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THE ANATOMICAL CHANGES IN THE STRUCTURE OF THE VASCULAR CYLINDER INCIDENT TO THE HYBRIDIZATION OF CATALPA.

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IN 1889 Prof. C. S. Sargent published an account of an interesting and newly observed case of hybridization between two species of Catalpa which he designated as Catalpa × J. C. Teas in reference to the origin of the tree in the nursery of Mr. Teas at Carthage, Missouri.[1] The account referred to states that *Catalpa kæmpferi* was planted in 1864 in a nursery containing *C. speciosa* and *C. bignonioides*. Eventually the first species produced a single pod of seeds which were wholly unlike anything hitherto known. When these seeds were planted, they produced a tree almost intermediate in character between *C. kæmpferi* and one of the American species. Mr. Teas was of the opinion that the cross was with *C. speciosa*, while Prof. Sargent considered *C. bignonioides* as the other parent, basing his conclusion upon the fact that *C. speciosa* flowers two to three weeks earlier than *C. kæmpferi*, while the flowers of *C. big-*

[1] *Garden and Forest*, vol. 2, 1889, p. 303.

nonioides are contemporaneous with those of the Japanese species. No other evidence has been forthcoming since then, so far as I am aware, and the real American parentage of a most noteworthy addition to the ornamental trees of this country still remains in doubt. Within the last twelve years, opportunities have been presented to inquire into the evidence which might be secured from an anatomical point of view, and to determine

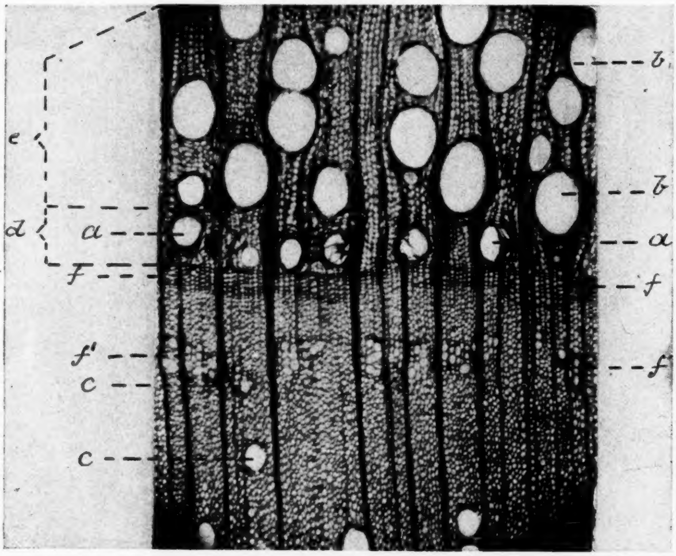


FIG. 1.—*Catalpa teasi.* Transverse section, × 44. *a*, vessels of the primary zone showing small size and few thyloses; *b*, vessels of the secondary zone abruptly much larger and chiefly devoid of thyloses; *c*, the greatly reduced and widely scattering vessels of the last growth of the season; *d*, narrow zone of thin-walled cells of the spring wood; *e*, cells of the summer wood; *f*, zone of spiral and scalariform tracheids forming a limiting layer of uniform width and chiefly without radial extensions, but repeated at *f'* in a second zone centering in the greatly reduced and more numerous vessels.

to what extent the external alterations attendant upon hybridization correspond with internal structural changes. It was felt that the answer to this question might very largely contribute to a solution of the difficult problems relating to the origin of species by either mutation or hybridization, and admit of a more precise limitation of the characters which define a species. The

importance of this latter point of view was the more strongly impressed upon me because, in the course of studies relating to the recognition of species among the North American Coniferales as determined by the anatomy of the woody axis, I had been obliged to adopt the working hypothesis that there are no varietal forms in the sense commonly employed and as expressed in variations of the external organs, and that where these variations arise, they define species as certainly, though not as conspicuously as in other cases. Fortunately I already had in my possession, wood of *C. bignonioides* and *C. speciosa*, while fresh material of the latter was also obtained from trees growing in the grounds of McGill University. About twenty years ago, a specimen of Teas hybrid was planted out in the College grounds, and it has proved perfectly hardy up to the present time, though two other specimens planted about eight years ago were completely killed during the two winters of 1902 and 1903. Recently Mr. Burton Landreth of Bristol, Pa., who possesses a growth of *C. kæmpferi*, very kindly sent me a specimen of wood, and it has thus become possible to bring the wood structure of the hybrid into direct comparison with that of the three species among which its parents are to be found. Later specimens of *C. kæmpferi* from Mr. J. G. Jack of the Arnold Arboretum, have also enabled me to institute more extended comparisons. Before proceeding to a discussion of the results obtained, it will be desirable to recall the essential features of the hybrid as given by Sargent, and to see the direction in which such evidence tends.

"The hybrid is an erect, vigorous and rapid growing tree, with the thin, scaly bark of the American species. The leaves of this tree are much larger than those of either of its parents, having, when they first appear, the velvety character and purple color peculiar to those of the Japanese plant, and the reddish spot at the insertion of the petiole with the leaf blade which characterizes that species. They more generally resemble those of the Japanese species in shape, color and texture, while the pubescence which covers the lower surface is almost intermediate in character between that of the American and of the Japanese species. The inflorescence is much larger than that of the American or of the Japanese plants, being fully twice as

large as that of *C. bignonioides* and more than three times the size of *C. kæmpferi*. The flowers are intermediate in size; in color and markings they most nearly resemble those of the American species, although a tinge of yellow in the throat of the corolla points to their Japanese descent. The fruit of the hybrid is almost intermediate in size between those of the two parents, as are the seeds, which are perfectly fertile and often

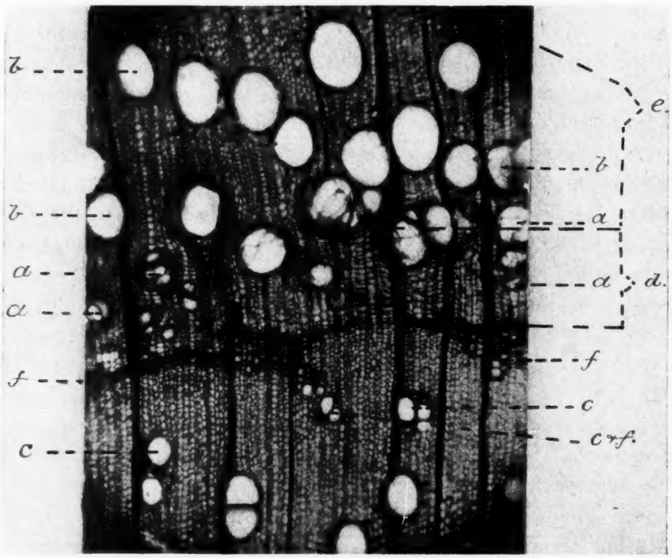


FIG. 2.—*Catalpa kæmpferi*. Transverse section, × 44. *a*, vessels of the primary zone with thyloses; *b*, vessels of the secondary zone showing great increase in size and diminution of the thyloses; *c*, vessels of the last of the season's growth; *d*, thin-walled cells of the spring wood; *e*, smaller and somewhat thicker-walled cells of the summer wood; *f*, zone of spiral and scalariform tracheids limiting the growth ring and showing radial extensions in connection with the last small vessels.

reproduce the original form in every particular. When, however, seedlings show a tendency to vary from the original form, the variation is generally in the direction of the Japanese rather than of the American parent."

"The hybrid is a more vigorous tree than either of the American or the Japanese species, and it grows rather more rapidly.

Of its value as an ornamental tree there can be no doubt. Its larger size and more rapid growth, its better habit and more showy inflorescence, make it a far more valuable ornamental tree than the Japanese species; it is more hardy than either of the North American species, and although the flowers are smaller, the panicles and the number of the individual flowers are much larger." The inflorescence of the hybrid is also remarkable for

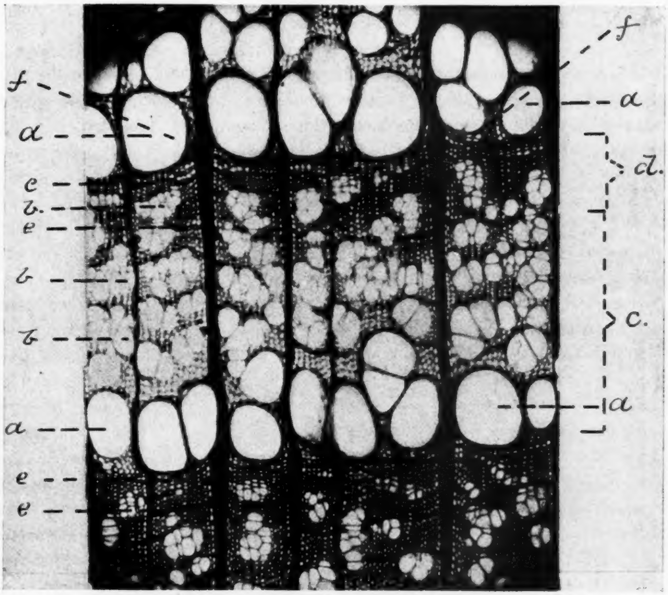


FIG. 3.—*Catalpa speciosa.* Transverse section, × 44. *a*, very large vessels of the primary zone without thyloses; *b*, small and much compounded vessels of the secondary zone, rather abruptly terminated in the outer region of the growth ring; *c*, the broad zone of the spring wood; *d*, the narrow zone of the summer wood; *e*, tangential and concentric bands of resinous wood parenchyma; *f*, the narrow, limiting zone of wood tracheids.

its prolonged duration which extends from June until September as presented by specimens grown here.

We may now turn to a study of the internal structure of the hybrid and of the three related species in order to determine (1) if the crossing has made an impress upon the anatomical structure, or if it is simply expressed in external characteristics; (2)

if there is any anatomical evidence which will determine the species with which *C. kæmpferi* was crossed; and (3) if this evidence bears any relation to the fixity of the form and in any way defines a new species. To this end it will be necessary to elaborate the separate diagnoses and compare them with one another, as also with differences in color, form, and texture as applicable to the leaves and flowers.

TEAS HYBRID (Figs. 1, 5).

Transverse.— Growth rings very broad, the spring wood thin but the distinction between it and the summer wood not clearly recognizable. The wood cells of the earliest growth sometimes tangentially elongated, in more or less obvious radial rows and rather large with rather thin walls; the structure of the later growth chiefly the same throughout the growth ring, the cells hexagonal, in somewhat definite radial rows, not thick-walled, very variable in size with little or no diminution toward the outer limits. Wood parenchyma confined to the composition of the vessels and to the earliest spring wood where the cells become distinctly larger and more resinous. Wood tracheids prominent, squarish, in very definite radial rows, forming a narrow zone of about six elements on the outer face of the growth ring, but locally extended radially inward opposite the smaller vessels with which they join so as to form tracts of variable width; also uniting with the smaller vessels to form a second and more internal, discontinuous zone of very irregular width and form. Vessels at first medium and forming a single layer with strongly developed thyloses; becoming abruptly larger in the second layer, radially oval or oblong and chiefly single, but sometimes 2–3 compounded radially and tangentially and largely devoid of thyloses; soon diminishing in size and number, radially compounded and much scattered in irregular groups of 2–6 throughout the growth ring, finally reduced somewhat abruptly in the last growth of the season to the dimensions of tracheids with which they coalesce into irregular tracts. Medullary rays prominent, numerous, somewhat resinous especially in the spring wood, 1–3 cells wide, distant upwards of 178 μ.

Radial.— Medullary rays somewhat resinous, the cells straight, rather uniform in height, very variable in length and from 3–4 times longer than high, or again very short and much higher; the upper and lower walls rather thick and finely pitted; the terminal walls straight or curved and finely pitted; the lateral walls not pitted except opposite vessels and then with small, numerous, oval and unequal pits. Tracheids of the limiting zone with spiral and scalariform structure which merges into 1–2 rows of simple pits on the radial walls. Wood parenchyma somewhat resinous and exceedingly variable; when adjacent to the spiral tracheids of the summer wood, very

narrowly cylindrical, when adjacent to vessels, usually short cylindrical and bearing numerous transversely oval or oblong pits on the radial walls. Vessels often much shorter than broad, the radial walls with multiseriate, hexagonal pits throughout, the orifice transversely oblong.

Tangential.— Rays very numerous, low to medium, 1–3 cells wide, somewhat resinous; the cells chiefly oblong, rather thin-walled, those of the extremities much larger and more variable. Vessels with multiseriate, hexagonal or more commonly oval, bordered pits which frequently become simple, distant, and transversely oval or oblong. The tangential walls of the wood parenchyma with numerous transversely oval or oblong pits. Tracheids often devoid of spiral and scalariform structure which is replaced by upwards of 3 rows of simple pits.

The features thus described will be found in the figures of

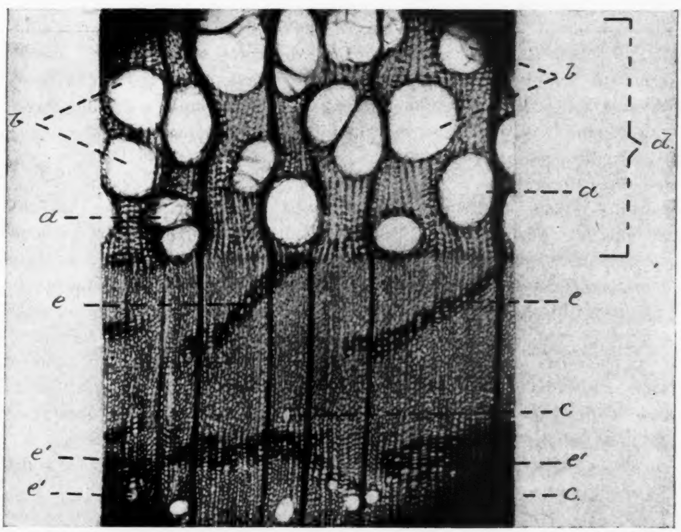


FIG. 4.—*Catalpa bignonioides.* Transverse section, × 44. *a*, very large vessels of the primary zone showing few thyloses; *b*, the vessels of the secondary zone chiefly without thyloses; *c*, the greatly reduced and distant vessels of the summer wood which do not appear prominently within a wide zone; *d*, the broad zone of the thin-walled cells of the spring wood; *e*, diagonally radial tracts of spiral and scalariform tracheids connecting with the outermost and most reduced vessels; *e′*, tangentially extended tracts of tracheids centering in larger vessels and forming an almost continuous, secondary zone.

the transverse and longitudinal sections. As one of the parents of this hybrid is known to be *C. kæmpferi*, its diagnosis may be

given and brought into direct comparison in order to ascertain what characters have been derived from it. By elimination it will then be possible to refer the remaining characters to either *C. speciosa* or *C. bignonioides.*

C. kæmpferi (Figs. 2, 6).

Transverse.— Growth rings very broad. Differentiation of the spring and summer woods well defined (?), the latter constituting the bulk of the growth ring and defined by a somewhat abrupt transition in the form, size, and thickness of wall of the component cells. The spring wood composed of large, variable, squarish-hexagonal and tangentially elongated, non-resinous, and thin-walled cells which form a limiting zone external to the previous growth ring; soon replaced by the somewhat abruptly smaller, rather thin-walled, hexagonal and radially elongated cells of the summer wood which diminish almost imperceptibly toward the outer face of the growth ring. Wood parenchyma strictly confined to the composition of the vessels. Tracheids conspicuously squarish, rather uniform, in regular radial rows, more or less resinous, rather thick-walled and forming a limiting layer upwards of six cells thick on the outer face of the summer wood, or opposite the most recently formed small vessels, joining with the latter to form radially extended tracts of irregular form and extent, or even forming detached groups centering in small vessels, so as to form a second zone of imperfect development. Vessels somewhat numerous and scattered throughout the growth ring; those of the early spring wood with strongly developed thyloses; at first rather small, numerous and round, but abruptly enlarging with the corresponding transition from the spring to the summer wood cells, and becoming oval or radially extended and 2–3 compounded in radial series, predominant; again abruptly reduced in size and number, sometimes radially 2–3 seriate, and thence continuing without much variation to the region of the outer summer wood where they are once more abruptly reduced in size and there give rise to the terminal layer of tracheids. Medullary rays prominent, sparingly resinous, 1–3 cells wide, distant upwards of 427 μ.

Radial.— Medullary rays sparingly resinous; the cells within the region of the early spring tracheids chiefly short; isodiametric; the upper and lower walls rather thick and strongly pitted; the terminal walls thicker and more strongly pitted; the lateral walls with numerous small pits in more or less definite radial series; in older parts of the growth ring the cells increase greatly in length, except the marginal ones which remain short and become much higher, the pits on the lateral walls opposite vessels become much larger and oval. Wood parenchyma of the spring wood composed of short and thin-walled cells which bear rather numerous, transversely oval, simple pits on the radial walls; those of the vessels of later

growth much longer and narrower. Tracheids of the summer wood narrow, spiral, scalariform, and pitted, and showing all transitional forms from simple spirals to hexagonal bordered pits in 1–3 series. The radial walls of the vessels with numerous hexagonal pits having rather large, transversely oval or oblong openings.

Tangential.— Medullary rays rather numerous, resinous, low to medium and 1–3, chiefly 2 cells wide; the cells rather thick-walled, hexagonal. Tangential walls of the vessels with numerous and variable, transversely oval, oblong or long linear, often simple pits. The tangential walls of the spring parenchyma with numerous round or transversely oval, chiefly simple pits; those of the early spring wood cells with transversely linear, narrow and rather numerous pits.

A comparison of the transverse and tangential sections for this species, with those for the hybrid, makes the general relations of the two very obvious, but a more critical examination of them is necessary. In each case the wood is characterized by the great breadth of the growth ring. In *C. kæmpferi,* the thin-walled spring wood constitutes a rather narrow zone representing but a small volume of the total growth for the season. Precisely the same is also true of the hybrid with the difference that the volume is reduced to about one half what is to be found in the former, showing the definite influence of one parent. In each case the wood parenchyma is confined to the composition of the vessels or to the earliest spring wood, and there is no feature in them which can be directly ascribed to *C. kæmpferi.* A very definite connection between *C. kæmpferi* and the hybrid, appears in the distribution of the tracheary tissue which, in the latter, forms a well defined limiting layer occupying the same position as in the former but characterized by greater uniformity of width. This is undoubtedly due to *C. kæmpferi* in the first instance, but ultimately it is to be regarded as a resultant effect from the interaction of the two parents as will appear later. In addition to the limiting zone of tracheids which sometimes extends radially inward as in *C. kæmpferi,* though not generally to the same extent or so frequently, it is to be noted that in the hybrid there is a second and more internal zone of tracheary tissue which centers in the small vessels of the outer summer wood and which forms tangentially extended tracts of a very well defined character. This feature is one of the most prominent structural

changes, and it points with great force and directness to the influence of some other parent than *C. kæmpferi*, although this has also exerted an influence. In the distribution, size, and character of the vessels, there are but few features which serve to guide us in forming a conclusion, but it will be noted that the

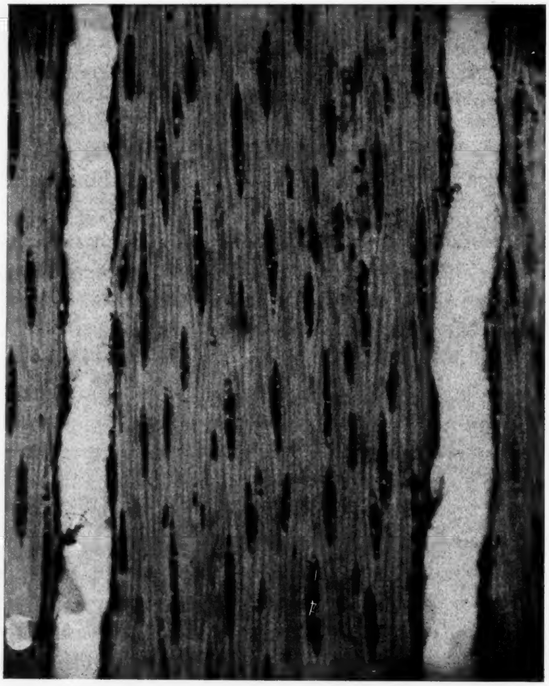


FIG. 5.—*Catalpa teasi.* Tangential section, × 61. Showing vessels with few or no thyloses, and the rather numerous and medium rays of lenticular form, 2–3 cells wide.

conspicuous thyloses of *C. kæmpferi* have practically disappeared in the hybrid though retained in the initial row of vessels which have increased slightly in size and are confined to a much narrower, radial zone. This points without doubt to the influence of the other parent. In the outer regions of the growth ring, the vessels are seen to be conspicuously smaller and on the

whole, more scattering in the hybrid than in *C. kæmpferi*, a feature undoubtedly derived from the other parent. The medullary rays offer no evidence of value in favor of either parent, since in each case they present the same features of structure.

In the structure of the medullary ray as presented in radial section, some features are worthy of consideration. The generally short, isodiametric cells of *C. kæmpferi* are more commonly replaced in the hybrid by longer and very variable cells, the upper, lower, and terminal walls of which are marked by fine pits, all of which features must have been derived from another parent than *C. kæmpferi* in which the walls are distinguished by coarse pits. While in the latter species the pits on the lateral walls of the cells are rather large and oval, in the hybrid they become small, numerous, and unequal. In each case the spiral and scalariform tracheids of the summer wood show transitional forms leading to the development of pits, but while in *C. kæmpferi* these latter structures are hexagonal, bordered, and in 1–3 series, in the hybrid they are usually simple and in 1–2 rows only, thus showing a modification which must be attributed to the other parent.

In a tangential section the medullary rays correspond in approximate number and height, as also in the number of series of cells entering into their composition, but while in *C. kæmpferi* the cells are rather thick-walled and hexagonal, in the hybrid they are rather thin-walled and oblong, the marginal cells becoming much higher and more variable. From this comparison it is obvious that *C. kæmpferi* has influenced the hybrid in very definite ways, while it is equally clear that the latter presents a number of characteristics which could have been derived only from *C. speciosa* or *C. bignonioides*, and in order to determine which, we may next compare *C. speciosa*. An inspection of a transverse section of this wood shows that it possesses features of structure which are in very marked contrast to what may be found in either of the preceding species, but in order to make these differences clear, a diagnosis may be given before proceeding to a detailed comparison.

C. speciosa (Figs. 3, 7).

Transverse. — Growth rings narrow, rather uniform, consisting of about one half spring and one half summer wood distinguished by their variations in (1) size of cells, (2) the thickness of the walls, and (3) the disposition of the cells. Cells of the spring wood large, thin-walled, hexagonal or sometimes tangentially extended, in somewhat obvious radial rows; those of the summer wood hexagonal, uniform, thick-walled, smaller and *not at all* in radial rows. Wood parenchyma dark and resinous, the cells forming tangential and concentric series at frequent intervals, chiefly in the summer wood. Wood tracheids thin-walled, few, in two or three rows terminating the growth ring as a layer of uniform thickness. Vessels of the earliest spring wood at first very large, oval or round, rarely compounded, and chiefly devoid of thyloses; quickly reduced and soon compounded in radial and tangential series and finally reduced to about twice the diameter of the wood cells; very numerous throughout the growth ring to which they impart an element of great porosity. Medullary rays somewhat numerous, dark, 1–several cells wide, distant upwards of 445 μ.

Radial.— Wood parenchyma abundant, the cells in parallel rows, 14.6 μ to 100 μ wide; sparingly resinous, the radial walls with rather numerous, small and simple pits. Medullary rays sparingly resinous; the cells chiefly uniform in height except the marginal ones which are very variable, short in the summer wood and upwards of 2½ times the height, or in the spring wood several times longer than high, the upper and lower walls sinuately unequal, rather thick, conspicuously pitted; the terminal walls straight, strongly but rather finely pitted; the lateral walls devoid of pits except opposite vessels where they commonly show a fine sieve-plate structure or are otherwise numerously pitted. Vessels chiefly rather short but very variable, the terminal walls rather thick but not pitted; the radial walls with multiseriate, very variable, hexagonal, round, oval, transversely oval or oblong, often much elongated and distant pits, the orifice finally becoming a much elongated, narrow slit without a border, thus showing transitions into scalariform structure. Radial walls of the spring wood cells with rather small, longitudinally oblong pits in vertical series. Tracheids of the summer wood interspersed with wood parenchyma, the radial walls spiral and scalariform and merging into rather small, oval, bordered pits upwards of 5-seriate.

Tangential. — Medullary rays numerous, low to very high, often equal to 2 mm., dark, resinous, one to unequally multiseriate and upwards of 5 cells wide; the cells small, round or oval, thick-walled, variable, the terminal cells commonly oblong. Wood parenchyma of the spring wood composed of short cylindrical cells with square or fusiform ends, the tangential walls with numerous, multiseriate but small, transversely oval, bordered pits. Tangential walls of the vessels with numerous small, multiseriate, hexagonal or transversely oval, bordered pits.

A careful analysis of this diagnosis shows that the most marked deviations from the characters embodied in the hybrid, are to be found in (1) the growth rings which are always several times less in radial extent and far more porous, (2) in the character of the initial layer of vessels which are always very large and devoid of thyloses, (3) in the character of the vessels of later

FIG. 6.—*Catalpa kæmpferi.* Tangential section, × 61. Showing vessels with numerous thyloses and the low, rather numerous rays of lenticular form, upwards of three cells wide.

growth, which are always much compounded and much smaller, their reduction from those of the initial layer being abrupt, (4) in the presence of numerous resinous wood parenchyma cells which lie in definite, concentric zones of one cell in width, (5) in the tangential aspect of the medullary rays which are exceedingly variable in height, of very unequal width and upwards of

5 cells wide. These features are of so pronounced a nature as to leave no doubt whatever as to the fact that *C. speciosa* is not in any way concerned in the production of the hybrid, since none of its characteristics are to be met with in the latter. It now becomes necessary to determine as a final factor, whether the features of the hybrid which we have already seen cannot be accounted for as being derived from *C. kæmpferi*, are in any way attributable to *C. bignonioides*.

C. bignonioides (Figs. 4, 8).

Transverse.— Growth rings very broad. The summer wood not sharply defined but distinguishable by (1) the smaller size of the wood cells, (2) the reduction of the vessels, and (3) the presence of groups or tracts of tracheids. Spring wood composed of large, variable, hexagonal, and tangentially elongated cells in somewhat obvious radial rows, the walls thin; soon replaced by the smaller and radially extended cells of the summer wood which diminish very gradually toward the outer limits of the growth ring. Wood parenchyma confined to the structure of the vessels. Tracheids rather thick-walled, non-resinous, squarish or tangentially extended, in radial rows confined to the outer portions of the growth ring where they form irregular and tangentially extended tracts of variable, often great extent in two series; the inner rather broad and strictly tangential, the rather large tracts more or less confluent and continuous, the outer formed of narrow, diagonal and chiefly free tracts projected inwardly from the outer limits of the growth ring. Vessels of the spring wood with strongly developed thyloses, at first large, oval or round, single and strongly predominant; soon becoming 2–3 compounded in radial series and steadily diminishing in size, shortly becoming single and more distant, and finally replaced wholly by groups of tracheids. Medullary rays prominent, 1–several cells wide, sparingly resinous, distant upwards of 462 μ.

Radial.— Medullary rays sparingly resinous; in the spring wood the cells are upwards of six times longer than high, the upper and lower walls very thin and barely pitted, the terminal walls thin and finely pitted, the lateral walls with occasional fine and simple pits; in the summer wood the cells are often not much longer than high, the upper and lower walls finally rather thick and strongly pitted, the terminal walls rather thick and finely pitted, the lateral walls when opposite vessels with rather small and commonly numerous, oval, simple pits in more or less definite radial series. Wood parenchyma of the first spring wood composed of short-cylindrical and rather broad cells, the radial walls with numerous, transversely oval or oblong, simple pits. The tracheids of the summer wood narrowly cylindrical and showing all transitional forms from spiral and scalariform to

small, transversely oval, and simple pits, or 2-seriate hexagonal bordered pits. Radial walls of the cells of the summer wood commonly with small, lenticular pits showing a cross. Radial walls of the vessels with multiseriate, hexagonal or even transversely oblong, distant pits, the thyloses with distant, linear and simple pits.

Tangential.— Rays rather narrow, medium to somewhat high, upwards of 3-seriate, the cells all thin-walled, hexagonal. Tangential walls of the vessels with multiseriate, oval pits, the narrow, linear orifice of which is transverse and often exceeding the pit. Pits on the tangential walls of the spring wood parenchyma often simple and transversely oblong.

The growth rings of *C. bignonioides* are seen to be very broad, thus conforming to what also appears characteristic of *C. kæmpferi*, and what arises as a necessary resultant in the hybrid, but constituting a feature entirely wanting in *C. speciosa*. Thus it appears that the growth rings in *C. speciosa* are approximately only one fifth of the radial dimensions in either the hybrid or *C. bignonioides*. While in general terms this difference may be said to exist, it cannot be taken as a differential character of leading importance for the reason that under certain circumstances of growth, the hybrid may develop equally narrow rings. Putting this factor to one side, we then find that the structure of the growth ring affords a very definite means of determining any possible relationship. The region which I consider as probably representing the spring wood, is several times broader than in *C. kæmpferi*, and the contraction of this zone in the hybrid must be viewed as due to the direct influence of the latter species. The vessels of the early spring wood are large and they increase in size for some distance within the limits of the spring wood, so as to form a rather broad zone without any well defined distinction of a primary and secondary zone as appears in *C. kæmpferi* and more prominently in the hybrid, and it is probably correct to say that the limitation in size and distribution which is expressed in the latter, is the direct result of the dominating influence of the large vessels of *C. bignonioides*. The influence of the latter is also expressed in the general distribution of the vessels. In *C. kæmpferi*, *C. bignonioides*, and the hybrid, the vessels gradually diminish in size toward the outer limits of the growth ring, but a comparison of their distribution in the first and last shows that the hybrid occupies an

intermediate position between the first two in such a manner as to show the direct influence of the latter in a reduction of both size and number in the outer summer wood. This feature is again correlated with the distribution of the tracheids. Our diagnoses have shown that in *C. kæmpferi* these elements form

FIG. 7.—*Catalpa speciosa.* Tangential section, × 61. Showing the vessels with rather few thyloses and the exceedingly high rays of variable width, composed of several rows of thick-walled cells.

a limiting zone which is locally increased in thickness in a radial direction opposite the small vessels of the outer summer wood, with which they coalesce to form irregular tracts; or again centering in small vessels so as to form a second zone of small and rather distant tracts. The same feature appears also in *C. bignonioides* but in such a modified form as to constitute a distinc-

tive character. Thus the tracheids lie in two zones. In the outer zone the tracheids form disconnected tracts of variable form and extent, which are rarely connected by a narrow zone of tracheary tissue on the outer face of the growth ring. These tracts are neither radial nor tangential in disposition, but the resultant of these two directions, and as they project diagonally

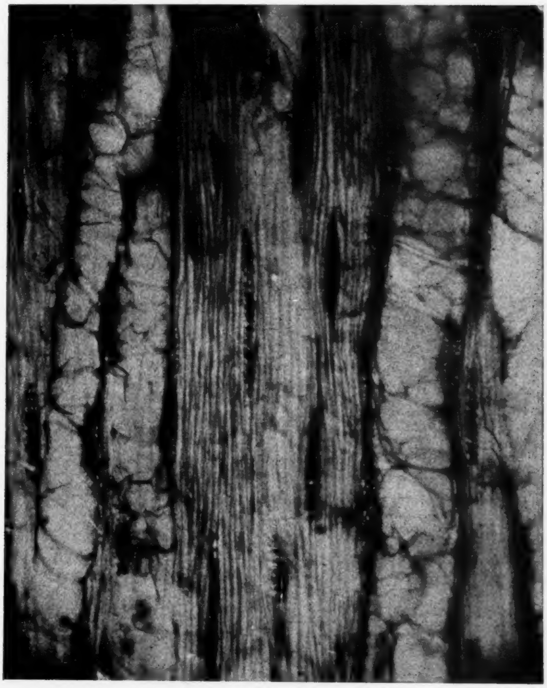


FIG. 8.—*Catalpa bignonioides*. Tangential section, × 61. Showing vessels with numerous thyloses and the medium to rather high, lenticular-oblong rays upwards of three cells wide.

inward, they join with very small vessels which constitute the final phase of such structures in the summer wood. In the second zone of tracheary tissue, the tracheids form tangentially extended tracts of variable form and size which are always connected with vessels of larger dimensions than those lying in the outer zone, and these tracts form an almost continuous series.

In the hybrid two such zones are also found. The inner zone is composed of tangentially extended tracts of variable form and size centering in vessels corresponding to those of the inner zone of *C. bignonioides* and presenting features which are intermediate between those of the latter species and *C. kæmpferi*. The direct influence of *C. bignonioides* is thus made very apparent. The outer zone of tracheids consists of a limiting layer of rather uniform thickness and generally devoid of vessels. Here and there a tendency to radial extension may be noted, but there is nowhere anything approaching what is to be met with in either *C. kæmpferi* or *C. bignonioides*, and the actual structural condition must be regarded as a resultant from the interaction of these two species, in which a somewhat equal influence appears to have been exerted.

In the radial aspect of structure, the influence of *C. bignonioides* is definitely expressed in the hybrid in (1) the more variable dimensions of the ray cells; (2) in the less coarsely pitted walls; (3) the 2-seriate character of the pits on the radial walls of the tracheids. In the tangential aspect, the influence of the same species is manifested in the thin walls of the ray cells, while the influence of *C. kæmpferi* is expressed in the character of the marginal cells. Other features of a minor character also contribute to the general results thus indicated, a summary of all of which may most conveniently be presented in a tabular view, from which I have excluded all characters common to the hybrid and to the three species.

Comparison of structural variations in Catalpa.

	Teas Hybrid.	*C. kæmpferi.*	*C. bignonioides.*	*C. speciosa.*	No.
Transverse.					
Growth rings very broad	×	×	×	—	3
Growth rings narrow, uniform	—	—	—	×	1
Spring and summer wood obvious	—	×	—	×	2
Spring and summer wood not distinguishable or locally defined	×	—	×	—	2
Cells of summer wood uniform, thick-walled, *not at all* in radial rows	—	—	—	×	1
Cells of summer wood variable, thin-walled in radial rows	×	×	×	—	3

	Teas Hybrid.	*C. kæmpferi.*	*C. bignonioides*	*C. speciosa.*	No.
Transverse.					
Wood parenchyma confined to the vessels and the earliest spring wood .	×	×	×	—	3
Wood parenchyma in tangential and concentric zones of a single layer throughout	—	—	—	×	1
Wood tracheids in radial rows on the outer face of the summer wood, radially extended opposite and confluent with the small vessels . . .	×	×	—	—	2
Wood tracheids forming two zones .	×	×	×	—	3
Wood tracheids forming irregular tangential tracts	×	×	×	—	3
Wood tracheids in a terminal layer of 2–3 rows	—	—	—	×	1
Vessels of early spring wood with thyloses	×	×	×	—	3
Vessels of early spring wood without thyloses	—	—	—	×	1
Vessels scattered throughout, often radially compounded	×	×	×	—	3
Vessels very numerous, chiefly small, radially and tangentially compound	—	—	—	×	1
Medullary rays 1–3 cells wide, low to medium, uniform	×	×	×	—	3
Medullary rays 1–5 cells wide, variable	—	—	—	×	1
Radial.					
Upper and lower walls of ray cells finely pitted	×	—	×	×	3
Upper and lower walls of the ray cells coarsely pitted	—	×	—	—	1
Tracheids with hexagonal pits in 1–3 series	—	×	—	—	1
Tracheids with 1–2 seriate bordered pits	—	—	×	—	1
Tracheids with hexagonal, very variable, multiseriate pits	—	—	—	×	1
Tracheids with simple pits in 1–2 rows	×	—	—	—	1
Vessels with multiseriate, hexagonal pits	×	×	×	—	3
Vessels with variable, often much elongated, slit-like pits merging into scalariform structure . . .	—	—	—	×	1
Tangential.					
Rays 1–3 cells wide, low to medium	×	×	×	—	3
Rays upwards of 5 cells wide, unequally multiseriate	—	—	—	×	1
Ray cells small, thick-walled, variable	—	—	—	×	1
Ray cells oblong, thin-walled . . .	×	—	—	—	1
Ray cells hexagonal, thin-walled . .	—	—	×	—	1
Ray cells hexagonal, thick-walled . .	—	×	—	—	1
Total characters	15	15	14	13	57

Percentages of characters.

(Those common to all are omitted.)

	Number.	Percent.
Hybrid + bignonioides + kæmpferi	10	31.2
Hybrid + speciosa	0	00.00
Hybrid + bignonioides	1	3.12
Hybrid + kæmpferi	1	3.12
Kæmpferi + bignonioides	0	00.00
Kæmpferi only	3	9.4
Bignonioides only	2	6.24
Hybrid only	2	6.24
Speciosa only	11	34.4
Speciosa + bignonioides	1	3.12
Speciosa + kæmpferi	1	3.
Total	32	99.84

From this percentage summary it appears that *C. speciosa* embodies 34.4 % of characters which are peculiar to itself, while *C. kæmpferi* and *C. bignonioides* possess 31.2 % of characters which are not only common to each other but also common to the hybrid, the remaining characters belonging, with one exception, either to these last two species or to the hybrid. From these facts therefore, we are abundantly justified in the following conclusions: —

1. Hybrid characters are expressed in the structure of the vascular cylinder as well as in external alterations of form and color.

2. *Catalpa speciosa* is not in any way concerned in the production of Teas Hybrid.

3. Teas Hybrid Catalpa is the product of a cross between *C. kæmpferi* and *C. bignonioides,* thus confirming the conclusions already reached by Sargent on the basis of external morphology.

4. The dominant characters of the hybrid, as expressed in the internal structure, are those of the Japanese parent as similarly manifested in the external characters.

5. The resultant characters are most strongly exhibited in transverse section, less so in the tangential, and least of all in the radial.

The question still remains unanswered, as to how far this hybrid approaches and satisfies the conditions which define a species. A complete solution of this question would be obtained in the most satisfactory manner by an anatomical study of reverted forms of the hybrid, were it possible to satisfy all the requisite conditions of authenticity, and determine to what extent the anatomical changes already found to characterize the hybrid, revert to the structure of the separate parents. Unfortunately such studies have not been possible under the conditions of the present investigation, and we are therefore compelled to fall back upon such partial evidence as is afforded by the external morphology. Reference to the original description of the hybrid shows that seedlings exhibit a decided tendency to reversion with respect to the character of the flower, and that such tendency is always in the direction of *C. kæmpferi*. This fact makes it clear that the Japanese parent exerts a dominant influence, while it also shows that the characters are not always fully fixed. Reference to the original description, however, makes it clear that such reversion is not displayed by *all* seedlings but only by *some*, results which are within the limits of justifiable anticipation and in strict accord with Mendel's law. Possibly our knowledge of all the changes incident to reversion is not as yet sufficiently complete to admit of a final expression of opinion as to the actual stability of the hybrid and its status as a species, but it may be kept in mind that while some seeds exhibit reversion, others come true to the hybrid form which is capable of perpetuating itself in succeeding generations. There is in this case no reason for supposing that this is any less a true species than large numbers of plants in which hybridization is an important factor as the starting point for a new line of development. With the abandonment of the old idea of fixity of species, and more particularly in the light of Mendel's law, we are led to see that in any case of hybridization there must be large numbers of progeny which, through reversion, ultimately disappear, while comparatively few acquire such stability as to survive in the form of what must be regarded as definite species. It is only on such grounds that we are justified in regarding as species the numerous and but slightly differentiated forms of the

willows, asters, and the Juglandaceæ which Prof. Sargent directs attention to as undoubtedly illustrating the effects of hybridization. Such potential species have always been a source of great difficulty to the systematic botanist who has been unable to properly define their limitations in such a way as to make them recognizable at all times and under all circumstances. The recent separation of six new species of violets from *V. cucullata* by Greene,[1] and the large number of species of Cratægus now recognized by Prof. Sargent can only be explained either as mutant forms or as new species according to the Mendelian law. Their acceptance as valid species shows that our former notions of the relations of hybrids and species have undergone radical change, and that we can no longer accept the limitations which were formerly supposed to be valid. If we are to accept as species those forms only in which there is no reversion to the parental type, and in which there is an absolute fixity of characters, then the hybrid in question cannot be regarded as a species; but if, on the other hand, we accept as species, as is now the custom, those forms which possess strongly defined potentialities, and in which the tendency to reversion is relatively weak, then the hybrid in question must be held to be a valid and distinct species as much as any other plants so defined, and in this sense it should be known as *C. teasi*, n. sp.

It only remains on the present occasion, to define the diagnosis for the genus Catalpa, and present a differential key for the recognition of the species, as follows: —

CATALPA.

Transverse.— Growth rings chiefly broad; the summer wood usually much exceeding the spring but the limitations not sharply defined. Wood parenchyma more or less resinous, often strongly so, generally associated with the vessels but sometimes forming concentric zones. Wood tracheids squarish and forming a limiting layer on the outer face of the growth ring from which irregular tracts may project radially inward, or again form a secondary zone. Vessels numerous, radially or sometimes tangentially compounded, with or without thyloses.

Radial.— Medullary rays somewhat resinous; the cells often higher than

[1] *Ottawa Nat.*, vol. 12, p. 181.

long, their upper, lower, and terminal walls rather thick and obviously pitted, their side walls pitted opposite vessels. Tracheids of the limiting zone spiral and scalariform and exhibiting transitions to bordered pits. Wood parenchyma cells variable but narrowly cylindrical, the radial walls with numerous transversely oval, simple pits. The radial walls of the vessels with numerous, multiseriate, hexagonal pits.

Tangential.— Rays usually numerous and multiseriate, the cells small and thick-walled.

Synopsis of Species.

Resinous wood parenchyma in concentric zones one cell thick.
- Vessels of the primary zone large, oval, devoid of thyloses; those of the secondary zone small, very numerous, much compounded.
  - Rays (tang'l) numerous, low to very high, unequally multiseriate, upwards of 5 cells wide.
    - Ray cells (tang'l) small, round or oval, thick-walled, variable. 1. *C. speciosa.*

Wood parenchyma sparingly resinous, the cells scattering and chiefly confined to the composition of the vessels.
- Vessels chiefly large, not much compounded, scattering and gradually diminishing toward the outer face of the growth ring.
  - Rays (tang'l) numerous, medium, 1–3 cells wide.
    - Wood tracheids in two zones; the outer composed of chiefly free, radially diagonal tracts; the inner of rather broad, variable and tangentially extended contiguous tracts forming an almost continuous zone.
      - Vessels of the primary zone large, oval or round, with few thyloses.
        - Ray cells (tang'l) thin-walled, hexagonal. 2. *C. bignonioides.*
  - Rays (tang'l) numerous, low to medium, 1–3 cells wide.
    - Wood tracheids in one zone, forming a continuous limiting layer with radial extensions opposite small vessels with which they unite, sometimes giving rise to detached groups which thus form a second, discontinuous zone.
      - Vessels of the primary zone small to medium, round, with strongly developed thyloses, abruptly enlarging in the secondary zone and finally becoming 2–3 compounded radially.
        - Ray cells (tang'l) rather thick-walled, hexagonal. 3. *C. kæmpferi.*
    - Wood tracheids in two well defined zones; those of the outer forming a continuous and rather uniform limiting layer upwards of 8 elements thick; those of the inner zone form-

ing a discontinuous tract of variable form and width.
Vessels of the primary zone in a single layer, small with sparingly developed thyloses, becoming abruptly larger and devoid of thyloses in the second zone, and finally sparingly compounded.
Ray cells (tang'l) chiefly oblong, rather thin-walled.
4. *C. teasi*, n. sp.

THE OCCURRENCE AND ORIGIN OF AMBER IN THE EASTERN UNITED STATES.[1]

ARTHUR HOLLICK.

A Recent Discovery of Amber in the Cretaceous Deposits at Kreischerville, N. Y.

Preliminary Note.— A recent discovery of amber in considerable quantity, in connection with the Cretaceous deposits at Kreischerville, Staten Island, N. Y., may be found briefly recorded by the writer in the *Proceedings* of the Natural Science Association of Staten Island for November 12th, 1904, but without any extended description or discussion. The discovery, however, was found to have aroused an unexpected interest in the subject, and the preparation of this paper was suggested.

Geologic Age and General Description of the Deposits.—The deposits in question consist of clays and sands which represent a part of the eastward extension of the Amboy clay series of New Jersey and are included in the Raritan formation, which is generally recognized as middle Cretaceous in age and approximately the equivalent of the Cenomanian of Europe, the lower Atane beds of Greenland, and the Dakota group of the West.

At Kreischerville they have been extensively excavated for economic purposes and in what is known as the Androvette pit a section was recently exposed, consisting of irregularly bedded clays and sands, referable to the geologic horizon above mentioned, overlain unconformably by more recent sands and gravels, the entire series showing more or less disturbance by glacial action. A view of a portion of the pit is shown in Plate 1.

Conditions Under Which the Amber Occurs.— The amber occurs in a stratum or bed, characterized by layers and closely packed masses of vegetable débris, consisting of leaves, twigs,

[1] Read before the Botanical Society of America, Philadelphia meeting, Dec. 30, 1904. Investigations prosecuted with the aid of a grant from the Society.

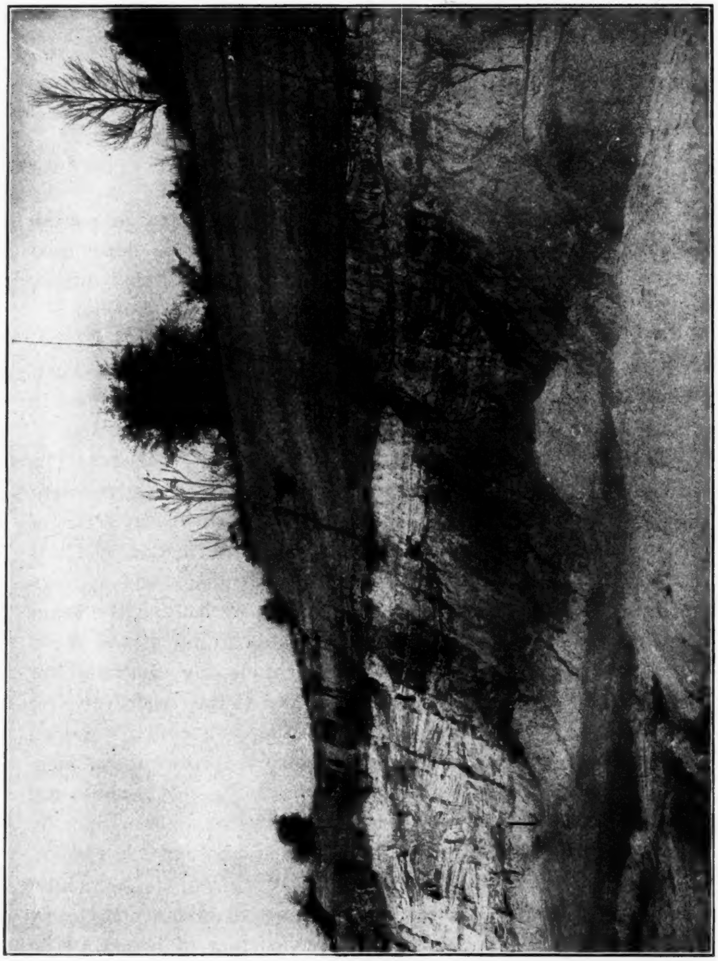


PLATE 1.—Section in Androvette pit, Kreischerville, Staten Island, N. Y., showing unconformity between Cretaceous clays and sands below and Tertiary or Pleistocene sands and gravels above.

and fragments of lignite and charred wood. Pyrite, in nodules, is also a prominent constituent. This bed, where exposed in vertical section, appears as if lens-shaped, having an indicated maximum thickness of about 3 feet and a lateral extent of 18 feet or more. The face of the pit at this place is about 20 feet high and the lower part of the bed is about 1 foot from the present floor of the pit. The section in which the bed is exposed is shown in Plate 2. It is immediately adjacent to the left of the section shown in Plate 1.

Most of the amber was found in a relatively thick accumulation of finely comminuted lignite and charred wood, of limited extent, through which it was irregularly distributed. This matrix yielded nearly all of the larger specimens and a majority of the smaller ones. The remainder were obtained from the relatively thinner layers of leaves and twigs. A piece of the lignitic matrix, with fragments of amber enclosed, is shown on Plate 3, Fig. 34.

Characters of the Amber.— A large part of the amber is in the form of drops or "tears," examples of which may be seen on Plate 3, Figs. 1–23, but irregularly shaped fragments, varying in size from a large pin's head to a hickory nut, are the most abundant. They are generally more or less transparent and yellow or reddish in color, but many are opaque and grayish white. Some of the best examples of the former are shown on Plate 3, Figs. 24–32, and a large piece of the latter on Plate 3, Fig. 33. The finest specimen in size, color, and transparency, represented by Fig. 32, is about 6 cu. cm. in volume. All of the figures on Plate 3 are of natural size.

Disposition of the Specimens.— Most of the specimens collected are deposited in the museum of the New York Botanical Garden and the remainder in that of the Natural Science Association of Staten Island. The only other specimens from this vicinity which I have been able to locate are included in the collections at Columbia University. These are three in number and are labeled respectively, "Marl pits, Squankum, N. J.," "Kirby's marl pit, Harrisonville, N. J.," and "Valentine's clay pit, Woodbridge, N. J." The last mentioned is of good quality and is about the size of a filbert nut.

Plate 2.—Section in Androvette pit, Kreischerville, Staten Island, N. Y., at extreme left of Plate 1, showing stratification of the Cretaceous deposits and bed, indicated by the pick, in which leaves and amber occur.

Previous Records of the Occurrence of Amber in the Eastern United States.

It is probable that amber is far more common in the Cretaceous deposits of the eastern United States than is generally supposed. The amount that may be obtained at the Kreischerville locality alone is considerable, as evidenced by the relatively large quantity that was obtained in the few hours devoted to the work, from the small portion of the exposure examined; and reports of its occurrence elsewhere indicate that careful search, with amber as the object in view, would produce excellent results.

Probably the earliest published record on the subject is contained in an article by G. Troost, entitled: "Description of a Variety of Amber and of a Fossil Substance supposed to be the Nest of an Insect, discovered at Cape Sable, Magothy River, Anne Arundel County, Maryland" (*Am. Journ. Sci.*, vol. 3, 1821, pp. 8–15), in which he describes the amber as occurring with lignite, and says (p. 9): "This lignite seems to be formed of three varieties of wood, or rather the wood has undergone three different changes, some pieces of which are entirely charred, often changed into bituminous wood, and others again having undergone very little change from the brown lignite. All these varieties, particularly the brown lignite and the charred wood, are penetrated by pyrites, and are sometimes entirely changed into it."

The above account is of considerable interest to us for the reason that the geologic horizon in which the amber was found at Cape Sable is approximately the equivalent of that at Kreischerville, and the conditions under which it occurs at both places are evidently identical. The meaning or significance of the charred wood presents an interesting problem, as it apparently indicates the direct effect of fire, at or immediately prior to the time when the deposits were laid down, and not that of any chemical change such as resulted in the gradual transformation of the wood into lignite. Further than this, its occurrence in such widely separated localities indicates that whatever the source of the heat may have been, the effects were far-reaching and extended over a considerable area. The same author, in the

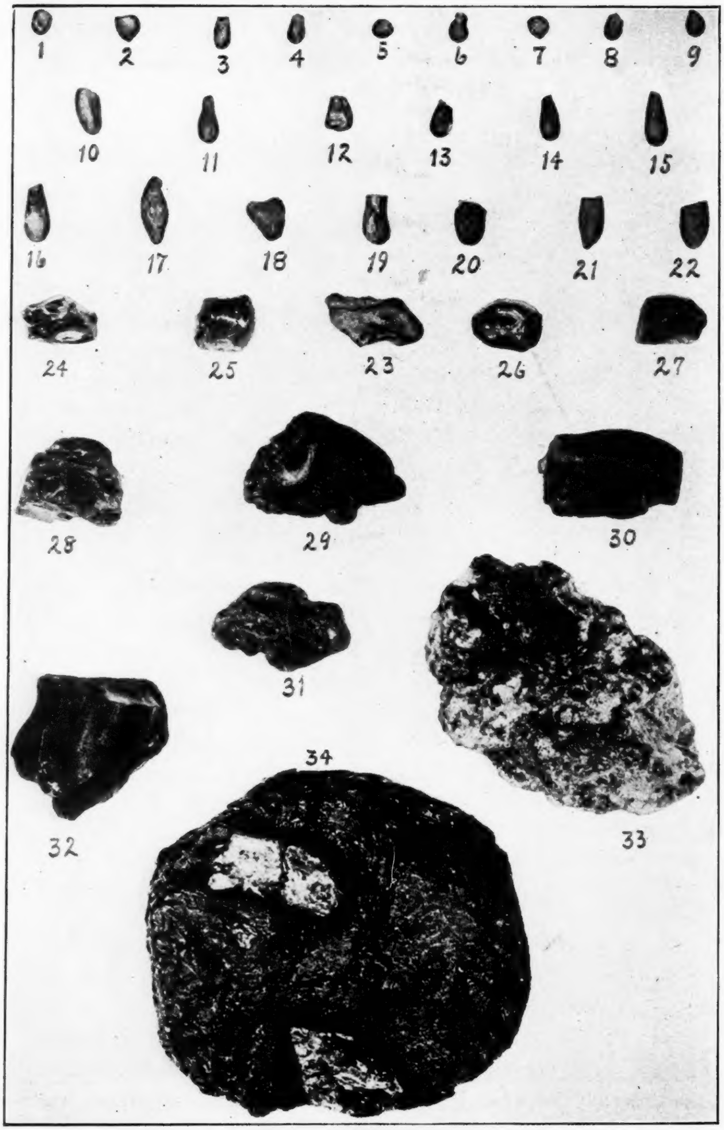


PLATE 3.

Figs. 1–23. Amber drops or "tears," Kreischerville, Staten Island, N. Y.
Figs. 24–33. Amber masses and fragments, Kreischerville, Staten Island, N. Y.
Fig. 34. Matrix containing amber, Kreischerville, Staten Island, N. Y.
(Figures are all natural size.)

article above quoted, also indulges in speculations concerning the kind of wood from which the amber was probably derived, and says (p. 13): "But I have not been able to ascertain the species to which it belongs."

Apparently nothing further was recorded in regard to the subject until 1830, when S. G. Morton published a paper entitled: "Synopsis of the Organic Remains of the Ferruginous Sand Formation of the United States, with Geological Remarks" (*Am. Journ. Sci.*, vol. 17, 1830, pp. 274–295) in which he mentions (p. 293) "vast deposits of lignite with amber," in the sections exposed in cuttings made for the Delaware and Chesapeake canal. Incidental reference to the above may also be found in a subsequent article "On the Analogy which exists between the Marl of New Jersey and the Chalk Formation of Europe" (*Ibid.*, vol. 22, 1832, pp. 90–95).

After this, for a period of some fifty years, our native amber apparently attracted but little attention, or at least there does not seem to have been anything additional recorded in regard to it during that time. A popular article, by Mrs. Erminnie A. Smith, entitled "Concerning Amber," was published in the *American Naturalist*, for March, 1880, in which the only reference in this connection is the following brief paragraph (p. 187): "Very little amber has as yet been found in the United States. Gay Head, Martha's Vineyard, Camden, N. J., and Cape Sable, Md., only are mentioned as its localities. A barrel full of small pieces was taken out of the greensand in New Jersey, which through some mistake was burned."

At a meeting of the New York Academy of Sciences, on February 5th, 1883, Mr. Geo. F. Kunz exhibited a mass of amber $\frac{3}{4}$ lb. in weight, which was said to have come from the Tertiary deposits of Nantucket, and read a paper "On a large Mass of Cretaceous Amber from Gloucester County, New Jersey," in which was described a mass weighing 64 oz., found in Kirby's marl pit, near Harrisonville (*Trans. N. Y. Acad. Sci.*, vol. 2, 1883, pp. 85–86). In the subsequent discussion of this paper Dr. J. S. Newberry is quoted as remarking that "in one pit [in Gloucester Co.] a whole barrel full had been found and burned by the workmen"; which remark probably has reference to the

incident mentioned in Mrs. Smith's article. In the record of this discussion may also be found a statement, credited to Mr. W. E. Hidden, to the effect that amber had been discovered during the previous summer in the marl beds of North Carolina, and a hearsay reference to a very large specimen from New Jersey, which was "found on the shore of Raritan Bay, and now deposited in the museum at Berlin, Germany."

In 1885 were made the first discoveries of fossil plant remains in the Kreischerville clays (*Proc.* Nat. Sci. Assn. Staten Isld., Dec. 12th, 1885). These were subsequently described by the writer (*Ibid.*, Feb. 13th, 1886) and at the end of the descriptions may be found the following brief paragraph: "There are also little masses of a yellow substance which I take to be a fossil gum or amber." Mr. Wm. T. Davis also found it there subsequently, according to the following record: "Mr. Davis presented unusually fine specimens of lignite, apparently coniferous, from the clay beds of Kreischerville. The specimens were of the appearance and consistency of jet and contained considerable amber," (*Ibid.*, March 12th, 1892). The above mentioned material from Kreischerville was all found in the immediate vicinity of the deposits recently exposed and probably from parts of the same bed.

Probable Origin of the Amber.

In 1894 the Cape Sable locality was visited by Mr. A. Bibbins, who succeeded in finding and collecting a number of specimens of amber, some of which were included in the interstices of a log of lignite and were evidently derived from it. This lignite was examined by Dr. F. H. Knowlton, by whom it was identified as a new species of Cupressinoxylon (*C. bibbinsi*), or in other words the fossil wood of a Sequoia ("American Amber-producing Tree," F. H. Knowlton, *Science*, vol. 3, 1896, pp. 582–584, figs. 1-4). This identification is important for the reason that it gives us definite information, for the first time, in regard to the origin of at least a portion of the amber in this part of the United States, and suggests a probable source for some of that at Kreischerville, where it occurs in close connec-

tion with the leafy twigs of *Sequoia heterophylla* Vel., and *S. reichenbachi* (Gein.) Heer. It may also be of interest to note that leaves of Sequoia are said to be associated with the amber of Japan.

Other coniferous remains which have been found in the Kreischerville clays, and which may have contributed to our supply of amber, are *Widdringtonites reichii* (Ett.) Heer., *Juniperus hypnoides* Heer, *Dammara microlepis* Heer., and Pinus sp. The genus Dammara is prominently represented in our living flora by *D. australis* Lamb, the well known "Kauri" gum tree of Australia. Its former existence, however, as an element in the Cretaceous flora of North America, is somewhat problematic, and is based entirely upon the presence of certain small cone scales, the exact botanical affinities of which have never been satisfactorily determined. The occurrence of remains of the genus Pinus is more significant perhaps than any of the other three last mentioned, by reason of the fact that the typical amber of the Baltic provinces in Europe is recognized as a product of the extinct Tertiary species, *P. succinifera* (Goepp.) Conw.

Acknowledgments.

For answers to letters of inquiry on my part I am indebted to Dr. Lester F. Ward and Dr. F. H. Knowlton of the United States National Museum, Mr. A. Bibbins of the Woman's College of Baltimore, Mr. L. P. Gratacap and Mr. Barnum Brown of the American Museum of Natural History, and to Mr. Geo. F. Kunz, of the United States Geological Survey.

FRESH-WATER RHIZOPODS FROM THE WHITE MOUNTAIN REGION OF NEW HAMPSHIRE.

JOSEPH A. CUSHMAN AND WILLIAM P. HENDERSON.

SINCE the publication of the *Monograph of the Fresh-water Rhizopods of North America*, by Dr. Joseph Leidy, little work has been done upon this very interesting group, especially as regards New England. Their abundance and the singular beauty of some of the species should make them better known even to the most casual observer of the microscopic fauna of our ponds and streams. The number of species obtained from New Hampshire was not great yet when compared with the whole number of shelled forms reported from North America it is a very fair representation. Certain forms found are apparently new and are reserved for further study.

The region from which most of the specimens were obtained was not of great altitude nor of high latitude but nevertheless both of these conditions seem to play an important part in the comparative size of the individuals of the same species. In the summary at the end of the present paper is discussed the bearing of these points as made out from a study of the material under observation.

The material used in the preparation of the present paper was of two kinds: mounted and unmounted. The former is in the collection of the Boston Society of Natural History and represents the following localities: Saco Lake, Profile Lake, Lonesome Lake, Lake of the Clouds, Pinkham Notch, Franconia, Claremont, Gilmore Pond near Profile House, and Scribner's Brook, Wakefield. The unmounted material was preserved in formalin and represents the following localities: Pudding Pond at North Conway; Intervale; a pond at 5000 feet on Mt. Munroe; Mirror Lake in Chatham (all collected by Dr. Glover M. Allen); North Woodstock (including two lots from the Flume, collected by George A. Fisher); Squam Lake (collected by Herman

Gammons); and Mt. Moosilauke (collected by Warren A. Priest). Identified specimens from this latter group of localities are preserved in the collections of the writers and are referred to by slide numbers under each species. For the other localities the number of the slide in the collection of the Boston Society of Natural History which contains an identified specimen is given. Thus all the localities and species may be verified by actual material. A mounted set of material from the second set of localities has been deposited in the collection of the New England Microscopical Society.

The arrangement of the genera and species follows that of Leidy's monograph. The determinations also follow the same work as it is still the standard work of its kind for our species. The following species and varieties were identified: —

Difflugia globulosa Dujardin.

The test of this species showed considerable variation. It was usually of coarse sand grains, but in some specimens included diatom valves, and in a few cases there was a chitinoid membrane with more or less extraneous matter attached to it. Several cases of dividing specimens were noted.

Size.— Length, 46–76 μ; breadth, 40–87 μ; diameter of aperture, 26–45 μ. As noted by Leidy, the specimens having the test composed of coarse sand grains are larger than those with a chitinous test.

Localities.— Mt. Munroe (Cushman Coll., nos. 193, 194); North Woodstock (Henderson Coll., no. 57, Cushman Coll., no. 181); Lake of the Clouds (B. S. N. H., no. 4319); Profile Lake (B. S. N. H., no. 4313); Franconia (B. S. N. H., no. 4307); Saco Lake (B. S. N. H., no. 4324).

Difflugia pyriformis Perty.

Test of coarse angular sand grains, sometimes with included diatom valves. Frequently the outline of the shell was broken by irregularly projecting quartz grains of large size. In a collection from Squam Lake were found several very large speci-

mens, the tests presenting a dark brown appearance. Whether this color was a result of the dark hue of the sand, or arose from a lining membrane of brown chitin in which the grains were incorporated, was not surely made out. One test was unique: trailing from many points in its surface were long blackish streamers, one even longer than the test. Several cases of division were seen.

Size.— Length, 68–309 μ; breadth, 35–201 μ; aperture, 15–87 μ.

Localities.— North Woodstock (Cushman Coll., nos. 183, 187, Henderson Coll., nos. 51, 53, 63); small pond, 5000 ft. alt., Mt. Munroe (Cushman Coll., no. 196); Franconia (B. S. N. H., no. 4307); Pinkham Notch (B. S. N. H., no. 5164); Squam Lake (Cushman Coll., no. 198); Intervale (Cushman Coll., nos. 66, 67).

Of *D. pyriformis* the following varieties described by Leidy, (p. 99) were found: var. *compressa*, North Woodstock; var. *nodosa*, Intervale; var. *vas*, Intervale.

Difflugia urceolata Carter.

Test of the typical form with the urceolate lip. As a rule, however, the lip was not as well marked as in the specimens figured by Leidy.

Size.— Length, 68 μ; breadth, 58 μ; aperture, 30 μ. This specimen is much smaller than that reported by Leidy.

Locality. — North Woodstock (Cushman Coll., no. 176).

Difflugia acuminata Ehrenberg.

Test as a rule of coarse sand grains with the fundus of the test drawn out into more or less of an acuminate projection. This species seems to differ more or less in its comparative breadth as all gradations were noted from very slender to fairly broad specimens.

Size.— Length, 87–125 μ; breadth, 46–60 μ; aperture, 22–31 μ.

Localities.— North Woodstock (Cushman Coll., nos. 182, 189); Intervale (Cushman Coll., no. 152).

Difflugia constricta (Ehrenberg).

Test usually of coarse sand grains; a yellow or brown chitinous membrane with irregularly scattered sand particles noted in one or two cases.

Size. — Length, 80–102 μ; breadth, 59–75 μ; aperture 22–37 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Claremont (B. S. N. H., no. 4662); Squam Lake (Cushman Coll., no. 199); North Woodstock (Henderson Coll., no. 62).

Difflugia spiralis Ehrenberg.

Test of varying construction, in one or two cases built up of the vermiform chitinous pellets shown in Leidy's Plate 19, figure 7; in others, of fine, straight, spicule-like fragments. In one, many diatom valves were used. The neck showed much variation in length.

Size. — Length, 44–126 μ; breadth, 38–96 μ; aperture, 12–46 μ.

Localities. — North Woodstock (Cushman Coll., nos. 182, 183, 190); Squam Lake (Cushman Coll., no. 197); Gilmore Pond near Profile House (B. S. N. H., no. 4314).

Hyalosphenia cuneata Stein.

Test of delicate chitinoid membrane, colorless and unornamented.

Size. — Length, 60 μ; breadth, 42 μ; aperture, 24 μ.

Locality. — North Woodstock (Henderson Coll., no. 53).

Hyalosphenia papilio Leidy.

Test a delicate and beautiful case of light straw-colored chitin.

Size. — Length, 111–118 μ; breadth, 67–69 μ; aperture, 31–32 μ.

Localities. — Mt. Munroe (Henderson Coll., no. 102); Mirror Lake, Chatham (Cushman Coll., no. 157).

Hyalosphenia elegans Leidy.

Test of yellowish brown chitin with the characteristic regular longitudinal corrugations. In the specimen examined a peculiar large irregular projection showed near the apex.

Size. — Length, 90 μ; breadth, 58 μ; aperture, 15 μ.

Locality. — Mt. Munroe (Henderson Coll., no. 101).

Quadrula symmetrica (Wallich).

Test as name suggests, composed of a tiling of delicate, unmarked, square, chitinoid plates. These plates increase in size toward the fundus.

Size. — Of specimens viewed on broader side, length, 58–78 μ; breadth, 28–46 μ; oval end, 14–21 μ. One rather larger, but turned so that a slightly oblique view of the narrower side was afforded, gave measurements: length, 87 μ; breadth, 33 μ; aperture, 7 μ. In this specimen the rounding notch of the aperture is visible.

Localities. — North Woodstock (Cushman Coll., no. 181, Henderson Coll., no. 63); Saco Lake (B. S. N. H., nos. 4235, 4325); Franconia (B. S. N. H., no. 4307); Pinkham Notch (B. S. N. H., no. 5148).

Nebela collaris (Ehrenberg).

Test in most of the specimens examined is composed of circular or ovoid plates, transparent and colorless. Several specimens showed straight or curved longitudinal plates mingled with the circular ones. One was bent strongly on one side giving a curved form to the shell.

Size. — Length, 65–196 μ; breadth, 44–108 μ; aperture, 14–46 μ.

Localities. — North Woodstock (Cushman Coll., nos. 176, 178, 180, Henderson Coll., nos. 52, 65); Lake of the Clouds (B. S. N. H., no. 4319); Profile Lake (B. S. N. H., no. 4313); Pinkham Notch (B. S. N. H., no. 5164); Saco Lake (B. S. N. H., nos. 4233, 4323); Mirror Lake, Chatham (Cushman Coll., nos. 156, 157).

Nebela flabellulum Leidy.

Test largely composed of circular disks much as in the preceding.

Size. — Length, 63–90 μ; breadth, 75–100 μ; aperture, 18–20 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Scribner's Brook, Wakefield (B. S. N. H., no. 4786); Mt. Moosilauke (Henderson Coll., no. 74).

Arcella vulgaris Ehrenberg.

Test a yellowish or brown chitinoid membrane, with minutely hexagonal cancellation. The common form of the upper surface is an evenly rounded dome, but two or three individuals showed top and sides depressed into bluntly angular facets.

Size. — Length, 42 μ; breadth, 23–54 μ; aperture, 11–15 μ.

Localities. — Mt. Munroe (Cushman Coll., no. 194); Saco Lake (B. S. N. H., nos. 4235, 4323).

Arcella discoides Ehrenberg.

Test of same material as in the preceding, in form more flattened.

Size. — Length, 29–44 μ; breadth, 77–108 μ; aperture, 19–42 μ.

Locality. — North Woodstock (Cushman Coll., nos. 176, 179, 198, Henderson Coll., nos. 54, 64).

Arcella mitrata Leidy.

Test of same material as in the preceding. In form, viewed either from above or from below, with the circular outline broken by the salient angles of the strongly marked facets. In side view, the shell is crown-shaped.

Size. — Length, 63–135 μ; breadth, 67–155 μ; aperture, 34–63 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Pudding Pond, North Conway (Henderson Coll., no. 70).

Centropyxis aculeata (Ehrenberg).

Test of yellow or brown chitin as in Arcella. In some of the specimens examined, quartz grains were incorporated in the membrane. The form is always characteristic: mouth and fundus eccentric in opposite directions. The typical form has several spines crowning the fundus.

Size.— Greater diameter, 89–153 μ; shorter diameter, 66–93 μ; aperture, 19–57 μ.

Localities.— North Woodstock (Henderson Coll., nos. 52, 60, 61); Squam Lake (Cushman Coll., no. 197); Pudding Pond, North Conway (Henderson Coll., no. 70); Intervale (Henderson Coll., nos. 66, 69); Gilmore Pond near Profile House (B. S. N. H., no. 4314); Claremont (B. S. N. H., no. 4662).

Centropyxis aculeata var. **ecornis** (Ehrenberg).

As the name implies, the fundus is not crowned with spines. One specimen examined showed the Arcella-like cancellation of the shell noted by Leidy (p. 183).

Size.— Average length, 48 μ; longer diameter, 48–144 μ; aperture, 12–41 μ.

Localities.— North Woodstock (Cushman Coll., no. 176, Henderson Coll., nos. 53, 62); Mt. Munroe (Cushman Coll., nos. 194, 196); Profile Lake (B. S. N. H., no. 4313); Franconia (B. S. N. H., no. 4307); Saco Lake (B. S. N. H., nos. 4325, 4324).

Cyphoderia ampulla (Ehrenberg).

The test in all specimens examined was of similar structure, and varied comparatively little in size. It is a delicate chitinoid membrane, colorless or faintly yellow, showing minute hexagonal cancellation; rim of oval aperture finely beaded.

Size.— Length, 104–143 μ; extreme breadth, 42–50 μ; aperture, 14–18 μ.

Localities.— North Woodstock (Cushman Coll., no. 189, Henderson Coll., nos. 51, 52, 63); Squam Lake (Cushman Coll., no. 198); Lake of the Clouds (B. S. N. H., no. 3719; Profile

Lake (B. S. N. H., no. 4313); Pudding Pond, North Conway (Henderson Coll., no. 71); Claremont (B. S. N. H., no. 4662).

Euglypha alveolata Dujardin.

Test chitinous, transparent and colorless. In form, generally a regular ovoid shape, truncated at the smaller end. One or two specimens were narrower and more flask-shaped. About half of the shells examined had spines.

Size.— Length, 48–91 μ; breadth, 31–46 μ; aperture, 12–18 μ.

Localities.— Profile Lake, Claremont, Franconia, and Saco Lake (B. S. N. H., nos. 4313, 4662, 4307, 4325).

Euglypha ciliata (Ehrenberg).

The plates in the tests of the specimens did not seem to overlap. In one specimen the cilia were few and long, in the others more numerous and shorter.

Size.— Length, 70–78 μ; breadth, 37–42 μ; aperture, 16–18 μ. These were all found in the valley and show little variety in size.

Localities.— North Woodstock (Cushman Coll., nos. 176, 181, Henderson Coll., no. 65); Intervale (Henderson Coll., no. 67); Profile Lake (B. S. N. H., no. 4213).

Trinema enchelys (Ehrenberg).

Closely corresponds to figure 1 of Plate 39 of Leidy.

Size.— Length, 81 μ; breadth, 44 μ; aperture, 16 μ.

Locality.— Franconia (B. S. N. H., no. 4307).

Acanthocystis chætophora Schrank.

But one specimen of this species was found and that was typical in every way.

Size.— Breadth with spines, 125 μ; breadth of body, 54 μ; length of spine, 24 μ.

Locality.— North Woodstock (Cushman Coll., no. 190).

Besides the recording of the species from this general region, one further use was made of this material: a comparison was made with the average measurements of Leidy. The results of this comparison may best be seen in the following table: —

	Lgth.	Bdth.	Aperture.		Lgth.	Bdth.	Aperture.	Leidy-Average. Lgth.	Bdth.	Aperture.
				Difflugia constricta.						
Intervale	178	117	49	Mt. Munroe	68	37	15	320	140	68
				Nebela collaris.						
Squam Lake	102	75	37	Lake of the Clouds	80	59	22	161	135	—
				Arcella mitrata.						
North Conway	—	155	63	Lake of the Clouds	—	67	34	—	142	50
				Centropyxis ecornis.						
North Woodstock	—	83	34	Mt. Munroe	—	59	28	—	146	64

From the above table, which represents the conditions seen in almost all the species under observation, the difference in size between the average measurements of Leidy for the whole of North America and the average measurements for this region is at once apparent. That this is due rather to latitude than altitude it seems safe to infer as the valley lakes are no higher than many of the medium records of Leidy. If it is safe to draw a conclusion from this, it at least seems to indicate that these animals are as a rule smaller in higher latitudes than in lower. Such a conclusion, of course, cannot be of great weight unless worked out in other cases, but is at least indicated here.

The other point which seems much more certain by direct comparisons in this same general locality is that some species are smaller on the tops of the mountains than they are in the valleys of the same region. In the first column are given the measurements of typical valley specimens and in the second column the measurements of specimens of the same species from lakes of about 5000 feet altitude. The differences in this case are at once marked and definite and it may be said with every degree of certainty for the species here worked out that a species at high altitudes will be smaller than the same species in lower altitudes of the same region. This one fact seems to repay the time spent in working up the various lots of material.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 162.

THE REACTIONS OF THE POMACE FLY (*DROSOPHILA AMPELOPHILA* LOEW) TO LIGHT, GRAVITY, AND MECHANICAL STIMULATION.

FREDERIC W. CARPENTER.

THE observations which this paper records were made on the movements of the common pomace or little fruit fly, *Drosophila ampelophila* Loew. Insects of this species can be collected in abundance in the autumn, and a culture can easily be maintained in the laboratory all winter if it is kept supplied with decaying fruit such as bananas or apples. The eggs are laid in this material, which later is used by the larvæ as food.

When a large cylindrical glass vessel containing a stock culture of these flies was placed on a table near a window, it was noticed that the flies accumulated in the greatest numbers on the upper part of the side of the vessel nearest the window. This indicated that they were positively phototropic to ordinary daylight, and probably negatively geotropic, although it seemed possible that their position near the top of the vessel might have been due to the fact that, owing to its position near the bottom of the window, the vessel was illuminated more brightly above than below. It was also observed that when the vessel was exposed to direct sunlight the flies, after a time, tended to accumulate, not on the surfaces toward or away from the window, but in intermediate positions on the two sides. Here the majority remained quiet in the regions of least illumination. A similar observation was made by Loeb ('93) on planarians, which

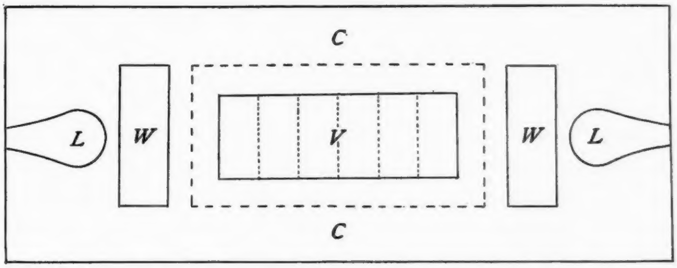
gradually came to rest in the darker portions of a shallow cylindrical glass vessel placed before a window. The large majority of the flies resting thus on the vertical sides of the vessel had their long axes parallel to the light rays, and their heads turned away from the source of light. Parker (:03) has pointed out that the mourning-cloak butterfly, coming to rest in bright sunlight, also places itself with the head away from the sun. The position assumed by the flies under these conditions might have led to the supposition that they had become negatively phototropic through continued exposure to an intensity of light higher than that to which they were accustomed. Such reversals have been observed for barnacle larvæ by Groom und Loeb ('90), for Hydra by Wilson ('91), for Polygordius larvæ by Loeb ('93), for Limax by Frandsen (:01), for copepods by Parker (:02) and for earthworms by Adams (:03). However, it was found that upon slightly turning the vessel on the table nearly every fly flew instantly toward the window, thus giving marked evidence of positive phototropism.

The experiments about to be described were undertaken with a view to obtaining some definite quantitative statements as to the influences of light and gravity on the movements of the organisms; and most particularly was it desired to test the responses of the flies to a range of high intensities of light. For valuable advice and aid in devising the apparatus and conducting the experiments the writer is indebted to Professor G. H. Parker, under whose supervision the work was carried on.

Apparatus.— In all of the operations the flies were confined in a cylindrical glass vessel measuring 15 cm. in length and 5 cm. in diameter, and closed at both ends by glass caps. Around the outside of the vessel were placed five small rubber bands at equal distances apart, the cylinder being thus divided into six sections each 2.5 cm. long. This subdivision of the vessel by surface markings enabled the observer to record the position of the contained fly at any moment with considerable precision.

In some of the experiments a dark box of convenient size was used, a sectional plan of which is given in the accompanying figure. This box was lined throughout with black cloth. In the center of each end wall was fixed an incandescent electric-light

bulb (L.), which projected into the interior. A determination of the amount of light given off from the *ends* of these bulbs showed each to have a candle power of approximately 5. The lighting of both these bulbs could be controlled from the outside by means of keys. A window let into one side of the box gave access to the interior when desired. This window could



Sectional Plan of Dark Box × ⅓. *C*, dark chamber; *L*, incandescent electric light of 5 c. p.; *V*, cylindrical glass vessel in which flies were contained; length, 15 cm., diameter. 5 cm.; distance of either end of this vessel from light, 7 cm.; the dotted transverse lines indicate the division into six sections by rubber bands; *W*, glass vessel containing water. The broken line surrounding *V* is a projection of the outline of the window of the dark box on the plane of this drawing.

be closed by a tight-fitting shutter. When the dark box was used the glass cylinder (V.), containing the flies, was placed within, midway between the free ends of the two electric-light bulbs, its axis coinciding with the straight line connecting these. The distance from either end of the cylinder to the adjacent electric light filament was 7 cm. Between each bulb and the cylinder was inserted, as a heat screen, a glass vessel (W.), filled with water, and having flat, vertical sides 3 cm. apart. Both the glass cylinder and the heat screens rested on strips of wood painted black; and these supports could be so arranged that the box, with cylinder and heat screens in place, could be used in either a horizontal or a vertical position.

Kinetic Effect of Mechanical Stimulation.— If in ordinary daylight a fly be placed in the glass cylinder, and this be held vertically, the fly will seek the top. If now the vessel be turned upside down the fly, finding itself at the bottom, will creep upward again to the top within considerably less, as a rule, than

one minute. In order to ascertain the behavior, under similar conditions, of flies deprived of light, both when allowed to remain quiet and when mechanically stimulated, the following experiment was undertaken, using the glass cylinder, but not the dark box described above.[1]

Two or three flies, the largest number easily worked with at one time, were put into the cylinder, and while exposed to daylight allowed to pass to its top section, whereupon it was quickly covered in such a way as to exclude all light, and the ends immediately reversed, the section containing the flies being thus made the bottom one. After having been left undisturbed for two minutes the cylinder was uncovered, and the positions of the flies on the sides of the vessel recorded. When they had again reached the top the vessel was placed in the dark again by steps similar to those just described, *viz.*, with the flies in the bottom section. At the end of one minute, however, the whole apparatus was this time revolved on the table top with friction for forty seconds so that the flies were mechanically agitated. Then after twenty seconds of quiet — making in all two minutes in darkness — the cover was removed, and the positions of the flies recorded as before. Periods of quiet in the dark were thus made to alternate with periods involving jarring until five readings for each set of flies had been made. Table I gives the combined records for three females and two males, the figures indicating the number of flies discovered in the sections of the cylinder at the end of two minutes in darkness. Section No. 1 is the uppermost, section No. 6 the lowest.

The table shows that the flies allowed to remain undisturbed were found in 16 instances in the lower half of the cylinder, and in 9 in the upper half, only 2 of these being in the top section; while those flies which were mechanically stimulated were distributed 10 in the lower half and 15 in the upper half, 7 of the latter number being in the top section.

[1] It might be mentioned here that throughout the observations male and female flies showed no consistent differences in their reactions.

Table I.

Distribution of five flies in a vertically placed glass cylinder after two minutes in darkness: the flies at the outset occupied the bottom section of the vessel, No. 6.

Sections of cylinder.	Numbers of trials.					Totals.
	Without mechanical stimulation.					
	1	2	3	4	5	
1		1		1		2
2		1		1	2	4
3		1	2			3
4						0
5	3	1		3		7
6	2	1	3		3	9
	With mechanical stimulation.					
	1	2	3	4	5	
1	1	1	2	3		7
2	2	1	1		2	6
3	1		1			2
4					1	1
5		1			1	2
6	1	2	1	2	1	7

Apparently, then, mechanical stimulation tends to induce the locomotion which results in this upward migration, or, in other words, it has a kinetic effect on the organisms. The direction of the movement indicates a negative response to gravity, a reaction which is more strikingly demonstrated in a succeeding experiment. The lesser degree of activity shown by the flies allowed to remain quietly in the darkness recalls the experiment of Loeb ('90) with plant lice, in which continued confinement in a dark chamber brought on a kind of "dark rigor" ("Dunkelstarre").

Kinetic Effect of Light.— To test the possible kinetic influence of light the following experiment was tried. The glass cylinder, containing a single fly, was placed in a vertical position in the

dark box, with an incandescent electric-light bulb at either end. The lower light only was at first turned on, and the fly thus attracted into the lower section. Then the window of the box was closed, the light turned out, and the fly left for one minute in darkness. At the end of this period both the upper and lower lights were turned on simultaneously, and at the expiration of another minute the window was opened and the position of the fly noted. Five readings were taken in this manner for each of six flies, three males and three females. When the results were combined (see Table II) it was seen that, out of a total of 30 readings, the flies had been detected 19 times in the upper half of the cylinder, no less than 16 of these observations being for the topmost section. In 11 cases the flies had remained below the middle of the cylinder.

Table II.

Distribution of six flies in a vertically placed glass cylinder after one minute's exposure to equal illumination above and below: the flies at the outset occupied the bottom section of the vessel, No. 6.

Sections of cylinder.	Number of trials.					Totals.
	1	2	3	4	5	
1	2	2	5	4	3	16
2	2	0	0	1	0	3
3	0	0	0	0	0	0
4	0	0	0	1	0	1
5	0	1	0	0	0	1
6	2	3	1	0	3	9

When this distribution is compared with that for flies left undisturbed in darkness for an equal length of time (Table I), it would appear that light acts as a stimulant to locomotion; and the rather striking efficiency of light in this respect is attested by the comparatively large number of flies found in the uppermost section of the cylinder.

Directive Effect of Light.— Experiments to demonstrate the directive effect of light of moderate intensity may be thought to

have been scarcely necessary since under natural conditions Drosophila gives such unquestionable evidence of positive phototropism. However, in order to obtain a more detailed expression of this, and to make the observations more complete, the glass cylinder, again containing a single fly, was placed horizontally in the dark box, and the lights on the right and left were alternately turned on and off. By this arrangement the influence of the light was brought to bear on the insect at right angles to the influence of gravity, which could not, therefore, affect the results. The window in the side of the dark box was left open in order that the movements of the fly might be watched. At the beginning of the experiment, when the insect was in the section of the cylinder the farthest to the left, the right light only was turned on. The fly would then creep toward the right along the sides of the cylinder. The time of the excursion from the line bounding the last section on the left to the one bounding the last section on the right was taken with a stop watch. As soon as the fly had crossed the last line on the right, the light at that end of the box was turned off, and the left light turned on. This change in the direction of the illumination was followed by a progression to the left on the part of the fly, an active insect setting out on the return excursion within an average time of about 10 seconds. The progress of the fly toward the left was also timed by the watch. Thus, by reversing the lights, the animal could be made to travel back and forth in accordance with the changes in the direction of the illumination. Flying responses occasionally took place, but, since these were difficult to time, they were not taken into account. Moreover, by neglecting these the records were kept homogeneous in that they were made for creeping excursions only. Individual insects differed considerably in the degree of activity they displayed, and often the same insect would respond less promptly at one time than at another. On those occasions when the kinetic influence of the light seemed for some reason to be partially inhibited, recourse was had to mechanical stimulation to bring the animal into a more active state. This was effected by removing the glass cylinder from the dark box and shaking it. Flies thus treated usually reacted more readily to the light rays for some time after.

In all, four flies, two males and two females, were used in this set of experiments. Each fly was sent five times in each direction. The average time for twenty creeping excursions toward the light from left to right, a distance of 10 cm., was 7.65 sec.; from right to left, 7.71 sec. The average rate in either direction was accordingly about the same, 1.3 cm. per sec. That Drosophila possesses the character of positive phototropism is obvious.

Directive Effect of Gravity.— By arranging the apparatus used in the phototropic experiment just described so that the glass cylinder had a vertical position, it was possible to test the directive effect of gravity on flies stimulated to action by light. The incandescent lamps were now situated one at the upper and one at the lower end of the cylinder, and alternately turned on and off. By means of a stop watch, time records of excursions along the vessel were taken as before. Not all the flies tested responded readily to the light, and preliminary mechanical stimulation produced by shaking the cylinder was sometimes resorted to. Finally two active male insects were found, for each of which five readings were obtained for each direction. The average time for ten creeping excursions toward the light from the bottom to the top of the cylinder through a distance of 10 cm. was 6.2 sec., or at a rate of 1.61 cm. per sec.; from the top to the bottom, 44 sec., or at a rate of 0.23 cm. per sec. The flies crept upward quickly and continuously, and at a rate slightly more rapid than that of flies in the cylinder placed horizontally. In their course downward they frequently stopped for short intervals.

The response to gravity accordingly appears to be a negative one, as was indicated by the behavior of the insects when mechanically stimulated in the dark. In the rapid upward excursions positive phototropism and negative geotropism coincided. In the slow downward ones these two influences were opposed, and although the directive influence of the light proved the stronger, the retarding effect of the opposed influence of gravity was apparent in the strikingly reduced rate of progression.

It happened occasionally that an insect would fly through a

portion of its excursion and alight on the vertical side of the cylinder. When this occurred the fly came to rest with its head uppermost, no matter whether its flight had been directed upward or downward. This orientation of the body on alighting may have been due to negative geotropism.

Effect of Increased Intensities of Light.— In order to subject the flies to light of different intensities use was made of an arc light suspended at one end of a dark room with dead black walls. The glass cylinder containing a single fly was placed horizontally on a small movable table, one end of the cylinder being directed toward the light. The movements of the fly were observed while the end of the cylinder through which the rays fell was at four different distances from the arc light, *viz.*, 800 cm., 300 cm., 80 cm., 40 cm. The candle power of the arc light used was approximately 64. Between the cylinder and the light a rectangular glass vessel containing 3500 cc. of water was interposed as a heat screen. The front and back walls of this vessel were 7 cm. apart.

At each of the four positions the responses of the fly were timed as follows. A small opaque screen was set up between the arc light and the cylinder, and at the opposite end of the cylinder an incandescent lamp was turned on. The fly, attracted by the light of the lamp, crept toward it. At the moment the insect reached the middle of the cylinder the screen obscuring the arc light was removed, the incandescent light extinguished, and the stop watch started. The fly, headed away from the arc light, usually stopped momentarily when suddenly exposed in this manner to the light from behind, and then resuming its course moved on until the opposite (dark) end of the cylinder was reached. Here it turned and hastened toward the illuminated end, either by creeping, or by flying, or by both creeping and flying. With the cylinder close to the arc light the fly sometimes turned about immediately upon the removal of the screen. When the fly crossed the boundary line of the section nearest the arc light the watch was stopped and the time recorded. At distances of 800 and 300 cm. a large majority of the responses were of the creeping kind. At positions nearer the light the insect often flew through a part of the distance —

sometimes through the entire distance. Since it was impossible to obtain pure creeping responses in all cases, those involving both creeping and flying were taken into account. Pure flying responses were not timed.

Observations were made on four flies, two males and two females, and the average time of twenty responses (five for each fly) at each of the four distances from the arc light was obtained. At 800 cm. and 300 cm. and even at 80 cm. the results did not materially differ, the average times of the responses at these three positions being respectively, 18 sec., 18 sec., 16.7 sec. At 40 cm. there was a marked increase in the rapidity of the movements of the flies, the average time of the responses being 7.4 sec.

The behavior of a fly under continued exposure to the highest intensity of light available for these experiments seemed to be of considerable interest. The apparatus used was the same as for the experiments last described, except that an arc light of greater candle power (250 c. p. approx.) was used. The procedure was also unchanged, the insect being brought up from a distance of 300 cm. to 80 cm. and finally to 40 cm. from the light. For each of the first two positions time records for five excursions were obtained, although those for 80 cm. required patient manipulation and many repetitions of the excursions, so numerous did the flying responses become. At 40 cm. the behavior of the fly was such that a full set of five readings could not be taken. Under the influence of the intense light the insect became extremely active, flying and leaping about spasmodically in all directions, and giving little or no evidence of directive responses. That is to say, the directive influence of the light was no longer effective enough to cause the fly to make excursions back and forth along the cylinder in accordance with the position of the illumination. While the fly was in this condition of great muscular activity, the screening off of the arc light and the turning on of the incandescent lamp, were followed by less activity on the part of the animal, but not by a progression toward the illuminated end of the vessel. The directive influence seemed to be for the time inhibited.

It appears, then, that continued exposure to a high intensity

of light produces very rapid locomotor movements, but while the kinetic effect of the light is thus increased, its orienting effect may be strikingly diminished. Throughout the experiments with high intensities there was no evidence of a change from positive to negative phototropism even under the influence of the highest intensity employed, that of a 250 c. p. arc light at a distance of 40 cm.

Discussion of Results.— In the preceding pages it has been found convenient to distinguish between two factors in the effect of light on Drosophila, a kinetic factor and a directive one. These two factors undoubtedly give rise to different kinds of responses, yet they are so closely related that it may be well to lay some stress on their interdependence. The directive effect of light manifests itself only in connection with a kinetic influence sufficient to induce locomotion. The insects while at rest do not regularly lie with their heads directed toward the source of illumination; in fact, those flies of the stock culture already referred to, which, after continued exposure to direct sunlight, came to rest in the least brightly illuminated portions of the vessel, were found with their heads turned away from the window. In the experiments with incandescent lights the turning on of one of the lamps was rarely if ever followed by mere orientation on the part of the fly, *i. e.*, simply an adjustment of the body in such a manner that its long axis became parallel with the light rays and that both eyes received an equal amount of light,— a condition of symmetrical stimulation which Loeb ('97) has maintained to be the essential factor of orientation. While the muscle reflexes necessary to put the insect in this position were usually forthcoming under such stimulation, these movements proved to be initiatory locomotor movements, being continuous with the series of locomotor reflexes which followed. When, on account of light-fatigue or other causes, the insect ceased moving about, no satisfactory evidence of orientation either to light or to gravity could be adduced from the position the animal assumed.

In the case of one fly subjected to the influence of a very high intensity of light, a reaction was obtained which involved only the kinetic factor. This fly while stimulated to great activity

did not appear longer to respond to the directive influence. Its movements were hap-hazard, not guided by the direction of the light, as if the organism, in its state of extreme excitement, had lost for a time its tendency to place itself when in motion under conditions of symmetrical stimulation. This violent kinetic effect of very intense light has been observed for several lower organisms by Pearl and Cole (:02). The conditions of their experiments did not permit them to note the effect on orientation. Long exposure produced a paralyzing effect, so that the movements became more and more slow as the stimulus continued to act. No insects were tested by them.

The experiments with the 64 c. p. arc light made it clear that when the intensity is increased by lessening the distance of the light from 80 cm. to 40 cm. there is a marked increase in the rapidity of true phototropic responses. This result in the case of Drosophila is certainly not due merely to more precise orientation, as was suggested by Davenport ('97) to explain the increase in the rate at which Daphnia traveled under strong light. It is interesting to note that Yerkes (:00), experimenting on the same organism (Daphnia), concluded that while the increase in rate depended chiefly upon precision and quickness of orientation, there was also evidence of a quickening of the swimming motions.

It was stated at the beginning of this paper that when the insects are exposed in a large cylindrical glass vessel, to direct sunlight from a window, many of them eventually come to rest on the sides of the vessel which are least illuminated. Their heads are in this instance directed away from the source of light. When disturbed by the vessel's being turned about they show positive phototropic responses by flying toward the light. This apparent negative orientation while at rest is not due, therefore, to a reversal of the directive influence of the light owing to continued exposure to a higher intensity.

It seems probable that the behavior of the flies under these conditions is the result of the following causes. When first exposed to the strong kinetic influence of bright sunlight Drosophila becomes very active. Its flying and creeping movements toward the light are limited by the wall of the vessel, and the

continued locomotor reflexes bring it into other regions. It may by accident reach the vertical surfaces of the vessel intermediate between the surface nearest and the one farthest from the window. Here the kinetic influence of the light, owing to decreased intensity, is least. The fatigued fly may still, however, be stimulated sufficiently to cause it to creep or at least to turn about. If it chances to place itself with the head directed away from the window, the reduced light stimulus received by the eyes may be inadequate to call forth further muscle reflexes, and the fly remains quiet in this position. Jarring the insect, or turning the vessel about so that more light enters the eyes, may increase the kinetic stimulation to such an extent that renewed movements are induced.

In Drosophila just as light causes locomotion, so mechanical stimulation seems to bring about progressive movements. From the nature of the case this stimulus was very roughly applied in the foregoing experiments, there being no effort to limit its application to one side of the body with a view to detecting its directive effect, if any, under such conditions. On the other hand, an allied form of stimulus, the pull of gravity, directs the movements of the organism, although it does not appear to induce them. A condition of symmetrical stimulation is undoubtedly brought about when, on a vertical surface, the fly places its long axis parallel to the direction of the lines of the earth's attraction. This pull of gravity on the materials which make up the animal's body differs more in degree than in kind from the impact of surrounding objects to which the animal is subjected when mechanical stimulation is applied. If the attraction of gravity and mechanical stimulation are regarded, then, as closely allied forms of stimuli, their two effects upon the organism admit of an almost exact comparison with the two effects of light. When left quietly in darkness, Drosophila gives little evidence of a tendency either to orient itself, or to move about. Thus gravity alone seems insufficient to induce either of these responses. When, however, the insect is mechanically stimulated, locomotor movements do occur, and in connection with them the directive influence of gravity becomes effective. The animal orients itself with its head away from

the center of the earth, and, responding to the kinetic influence of mechanical stimulation, moves upward. The general result is a progression in a definite direction, precisely such as is obtained when a light is placed at one end of a horizontal glass cylinder containing the insect.

Summary of Results.— 1. Mechanical stimulation has a kinetic effect upon Drosophila, since it induces locomotion.

2. Gravity has a directive effect upon the active insect, which is negatively geotropic, that is, the insect moves away from the center of the earth.

3. Light has both a kinetic and a directive effect. The insect moves toward the source of light, being positively phototropic. The directive effect is apparent only when the kinetic stimulus is sufficient to induce locomotion.

4. The exposure of Drosophila to light of high intensity is accompanied by an increase in the kinetic effect. Under the influence of the highest intensity used, that of a 250 c. p. arc light at 40 cm., the muscle reflexes of an insect become very rapid and violent, and the directive influence of the light seems inhibited. There is no indication of a reversal of the directive influence from positive to negative.

5. After continued exposure to direct sunlight in a large cylindrical glass vessel many insects come to rest in the least brightly illuminated regions and with their heads away from the source of light. This is not an indication of negative phototropism. The fatigued insects remain quiet in this position because it is the one in which the least light enters the eyes, and in which, as a consequence, the kinetic stimulus is least.

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NOTES AND LITERATURE.

GENERAL BIOLOGY.

Le Dantec's Treatise on Biology.[1] — The author of this considerable volume is well known from a number of general treatises of a popular nature all characterized by an agreeable style, but written rather freely, not to say speculatively; that is, not based at every step on ascertained fact. His works are what we are accustomed to think of as typically French, as opposed to the typically German treatises that build up a science out of numberless bricks of recorded observations (all fully referred to bibliographically) laid down in orderly fashion.

Le Dantec's volume is readable but not epoch-making. In places it introduces the reader to the very latest ideas — as in the suggestive chapter (V) on The Generation with Chromosomes and Sexual Parasitism. In other places it seems to bring us back to an earlier age, as in the discussion of the formation of species — species being defined as groups whose hybrids are sterile.

The author treats of many things, as a glance at the Table of Contents shows: chemical activity in a liquid plasm; assimilation; chemical and histological complexity; sexuality; sexual parasitism; heredity; acquired characters; amphimixis; the determination of somatic sex; life and death; the formation of species; histological differentiation of Metazoa; parallelism of psychology and physiology; and, lastly, "la liberté et l'égalité" among animals.

The book is clearly written and will be read by many interested in semispeculative biology based, for the most part, on recent knowledge; but considering its lack of bibliographic citations and its somewhat glib treatment of difficult subjects it cannot be considered indispensable to the worker.

C. B. D.

Organic Evolution.[2] — The author states in his preface that this

[1] Le Dantec, Felix. *Traité de Biologie.* Paris. Alcan, 1903. 8vo, 553 pp. 101 figs. in text. 15 francs.

[2] Metcalf, M. M. *An Outline of the Theory of Organic Evolution, with a Description of some of the Phenomena which it explains.* New York. Macmillan Co., 1904. 8vo, xxii + 204 pp., 143 pls., and 46 text-figs.

book "is not intended for biologists, but rather for those who would like a brief introductory outline of this important phase of biological theory." Nevertheless it will doubtless prove a very useful work in the hands of beginners in biology and of the "nature-study" teacher, and is sure to be attractive to the general reader because of the wealth of illustrative material which it contains. This material has been selected with great care and forms an integral part of the work. It is one of the best of the popular treatises on evolution.

W. E. C.

BOTANY.

Plant-Breeding.[1] — This useful and deservedly popular handbook, originally published in 1895, now appears in a third edition, revised so as to cover the important period since 1900, when Mendel's law was rediscovered. The work meets the needs of a wide circle of readers, including the general public particularly interested at the present time in the subject of horticulture, the practical plant-breeder, and the student. To the student the extensive bibliography appended to the book will be especially valuable.

W. E. C.

Haberlandt's Physiological Anatomy of Plants.[2]— It is now twenty years since the first edition of this work appeared and despite the mass of new material which has accumulated in that time, the author is able to adhere to his original plan in the exposition of the structures and functions of plant tissues. There is, indeed, not so much difference between this third edition and the second published in 1896, as there was between the last named and the first imprint of 1884. Nevertheless there is a considerable amount of new material, as is shown by the fact that the number of pages has increased from 550 to 616, and that the illustrations number 29 more in the new edition.

[1] Bailey, L. H. *Plant-breeding, being five Lectures upon the Amelioration of Domestic Plants.* New York. Macmillan Co., 1904. 16mo, 3d edition. xiii + 334 pp., frontispiece and 20 text-figs.

[2] Haberlandt, G. *Physiologische Pflanzenanatomie.* Leipzig. Engelmann, 1904. 8vo, 3rd edition. xvi + 616 pp., 264 figs. in text.

It is near the end of the book that the greatest change is to be noticed. In place of the eleventh chapter on tissues for special functions, we find the subject augmented to three chapters as follows: tissues for movement, sense organs, and tissues for conducting stimuli. In the first is an account of the passive hygroscopic movements of certain plant parts, and of the active movement, as seen in pulvini, stamens, etc. In the second is an elaborate treatment of the statolith theory, as well as descriptions of various forms of sensitive hairs and papillæ. In the third part the writer considers the propagation of stimulus in Mimosa, and in his explanation adheres to his former point of view. Here also he gives an account of *inter-* and *intra-*cellular conduction of stimuli.

Haberlandt's treatment of anatomy well deserves the prefix physiological, and stands, as it is intended to, in striking contrast to the mere topographical anatomy of many other writers. Any hard and fast system must naturally have a narrowing influence and a too ready acceptance of all the classifications of tissues and interpretations of functions in Haberlandt's book would no doubt lead the reader into the sloughs of teleology. We can however make what reservations we wish in his causal explanations and still have left a wonderfully suggestive and stimulating analysis of the aspects of plant tissues, viewed from a functional standpoint. That the author may at times carry this idea of the purposeful development of tissues too far, cannot be denied, yet even this is better than a purely formal treatment of the subject from a regional standpoint only. At least there is impressed upon the reader that plant tissues have functions, and that these functions constitute a real interest in the study of anatomy. In these days of increased interest in physiological problems and of the advance in knowledge of physiological processes, such a book as this will come more and more into consideration. The physiologist and ecologist, whether or no they always agree with the author, must frequently have occasion to consult the book and it may be suggested that the topographical and phylogenetic anatomist would do well to pay greater attention to Haberlandt's point of view.

There is one thing omitted from the book which should perhaps have found place, namely, a closing chapter by way of a general summing up of the inter-relations of the various "systems," so that a more complete picture of the plant as a whole might be obtained. The section of half-a-dozen pages in the first chapter, in which the physiological efficiency of the tissues is treated, does not fill the

want, which could best be supplied at the end, after all the types of tissues had been taken up. Possibly the author has purposely left the reader to construct for himself this picture of the plant as a whole.

The appearance of a book as valuable as this in a foreign language, always brings with it a certain regret when there is no similar work available in English. Excellent as it is, the translation of DeBary's anatomy is now very far behind the times and there is no other detailed account of plant anatomy in our language. In common with many others we hope that a translation of this third edition of Haberlandt's work will not be long in forthcoming.

H. M. R.

British Fresh-water Algæ.[1] — In his treatise on the British Fresh-water Algæ, G. S. West gives a general view of this group, based largely upon his own studies of the British Algæ. The great changes that have been made in recent years and the consequent limiting of the usefulness of previous monographs is noted. The need of a monograph of the fresh-water Algæ which may be used to determine the genera and species is also called to one's attention. The book contains many new facts concerning life histories, development, and relationships of the Algæ. It is illustrated by a large number of text-figures most of which are original and the localities from which the specimens were taken are noted. The Peridineæ and Characeæ are left out as not being certainly true Algæ. Besides a short preface, there is an introduction in which, after disposing of the historical considerations, the author discusses the occurrence, collection, preservation, and cultivation of the Algæ. Another chapter is devoted to a brief consideration of the six classes of the fresh-water Algæ, their vegetative, asexual and sexual reproduction, polymorphism; and the remainder of the chapter is given over to a discussion of the phylogeny and classification, which is based on the latest work on the various groups. The main portion of the book deals with the various classes, orders, and families, with a full description of each genus. As a rule each genus is illustrated, often by more than one species. Under each genus are brief notes and accurate measurements of the British species most frequently met with. The work recognizes the law of priority in dealing with the names of the genera, thus tending to fix in general use certain older but much less generally used names.

J. A. C.

[1] West, G. S. *British Fresh-water Algæ.* Cambridge Biol. Series, Cambridge Univ. Press, 1904. 8vo, xv + 373 pp., 166 figs. in text. 10/6.

British Desmidiaceæ.[1]—There has lately appeared the first volume of the *Monograph of the British Desmidiaceæ* by W. West and G. S. West. This is the third monograph that has been written on British desmids. The first was by Ralfs, in 1848, the second by Cooke, in 1887, the latter being mainly a compilation. Since the publication of Cook's work there have been 400 species and 402 varieties added to the desmid flora of Great Britain. The present volume is prefaced by a brief historical account. A very full bibliography takes up the twenty pages preceding the introduction. In the introduction a very complete general account of the family is given, especial attention being paid to the cytological characters. A number of pages are devoted to the discussion of the following points: variation, locomotion, vegetative, asexual and sexual reproduction, phylogenetic relationships, occurrence and distribution, collection and preservation, examination and specific determination. A diagrammatic table is given showing the phylogeny as worked out by the junior author a few years ago. The arrangement of the genera follows this scheme and an analytical key is given to all the genera recognized on this basis. This includes thirty-one genera, five of which have not been found in the British Isles. The remainder of the volume is given up to the systematic treatment of twelve genera, concluding with Tetmemorus. Under each species or varietal name appear the following points: a short synonymy, brief diagnosis including the zygospore, when known, and the range of measurements, the British localities grouped under England, Wales, Scotland, and Ireland, the geographical distribution as far as known, followed usually by certain critical remarks. As a rule the tendency seems to be to reduce the number of species and varieties instead of to increase, as is usually the tendency. One new species, ***Mesotænium truncatum***, and several new varieties are described. The volume is illustrated by thirty-two plates, containing about six hundred figures, of which most are original and many are colored.

J. A. C.

[1] West, W., and West, G. S. *Monograph of the British Desmidiaceæ*, Vol. 1. London, Ray Society, 1904. 8vo, xxxvi + 224 pp., 32 pls.

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